Title: Review of the "Outer Space Act (1986)" **IA No:** BIS0067 **Lead department or agency:** The Department for Business, Innovation and Skills **Other departments or agencies:** The UK Space Agency	Impact Assessment (IA) **Date:** 20/06/2013 **Stage:** Final **Source of intervention:** Domestic **Type of measure:** Secondary legislation **Contact for enquiries:** Jamie Crawford 0114 207 5328 **jamie.**crawford@bis.gsi.gov.uk

Summary: Intervention and Options

RPC Opinion: Awaiting Scrutiny

Cost of Preferred (or more likely) Option				
Total Net Present Value	**Business Net Present Value**	**Net cost to business per year** (EANCB on 2009 prices)	**In scope of One-In, One-Out?**	**Measure qualifies as**
£11.70	£ 13.55	£-0.96	Yes	OUT

What is the problem under consideration? Why is government intervention necessary?

The UK Outer Space Act 1986 and its licensing regime for UK space activities have continued without amendment for over 20 years. The UK Space Agency (UKSA) has carried out a formal review of the licensing system and identified areas where there is room for improvement. In particular, the treatment of contingent liabilities under the Act is inconsistent with practice in other space faring nations and in other UK sectors that have comparable contingent liabilities (e.g. nuclear power, offshore oil). The uncertainty surrounding contingent liabilities mean that premiums charged by insurance companies are higher than a functioning market price, leading to UK satellite operators being at a global competitive disadvantage.

What are the policy objectives and the intended effects?

To balance the risks to Government arising from UK space activity with the need to enable UK industry to exploit fully the opportunities available to them and to compete on a level playing field in the global space industry whilst also allowing better global access to the UK market. To address anomalies in comparison with other countries in the way the UK treats contingent liabilities arising from space activities and between the way contingent liabilities arising from space activities are treated in comparison with other UK sectors. The proposals will aim to improve certainty for the industry to operate and improve competiton in global markets by bringing legislation in line with other countries'.

What policy options have been considered, including any alternatives to regulation? Please justify preferred option (further details in Evidence Base)

Option 0 – Do nothing.

Option 1 – Adopt each of the proposals below:

Option 2: to remove the requirement for unlimited indemnity from satellite operators. Private companies' unlimited liability would be capped at €60m, and the UK Government would be liable for covering the remainder of any third party liability claims pursuant to the UN Treaty on Outer Space. In line with this, the insurance requirement for licensees would be reduced from £100m to €60m in the case of third party liability (TPL) cover. Note that the governments preferred option is option 2.

Option 3: Capped liability and insurance requirement waived for in-orbit operation of any satellite that meets the criteria of a CubeSat.

Will the policy be reviewed? It will be reviewed. **If applicable, set review date:** 06/2018

Does implementation go beyond minimum EU requirements?			N/A		
Are any of these organisations in scope? If Micros not exempted set out reason in Evidence Base.	**Micro** Yes	**< 20** Yes	**Small** Yes	**Medium** Yes	**Large** Yes
What is the CO_2 equivalent change in greenhouse gas emissions? (Million tonnes CO_2 equivalent)			**Traded:** N/A	**Non-traded:** N/A	

I have read the Impact Assessment and I am satisfied that (a) it represents a fair and reasonable view of the expected costs, benefits and impact of the policy, and (b) that the benefits justify the costs.

Signed by the responsible SELECT SIGNATORY: ______________________ Date: ______________

Summary: Analysis & Evidence — Policy Option 1

Description: To adopt policy options 2 and 3: To remove the unlimited indemnity/ reduce insurance requirement for licensees and the capped liability/ insurance requirement waived for in-orbit operation of cubesat

FULL ECONOMIC ASSESSMENT

Price Base Year 2012	PV Base Year 2013	Time Period Years 15	Net Benefit (Present Value (PV)) (£m)		
			Low: 10.02	**High:** 13.43	**Best Estimate:** 11.70

COSTS (£m)	**Total Transition** (Constant Price)	Years	**Average Annual** (excl. Transition) (Constant Price)	**Total Cost** (Present Value)
Low	0		0.1	**0.8**
High	0		0.2	**2.9**
Best Estimate	0		0.2	**1.8**

Description and scale of key monetised costs by 'main affected groups'

Increased contingent liability faced by UK Government from third party liability (TPL) claims arising from the launch or in-orbit operation of UK satellites.

As figures for policy option 3 are only made on a per CubeSat basis, they are not included here.

Other key non-monetised costs by 'main affected groups'

There would be an additional cost of £132 per UK CubeSat launched faced by HMG from the in-orbit operation of these micro satellites. There is no evidence to suggest how many of these may be launched – there are currently 40 in orbit, none of which are UK owned.

BENEFITS (£m)	**Total Transition** (Constant Price)	Years	**Average Annual** (excl. Transition) (Constant Price)	**Total Benefit** (Present Value)
Low	0		0.9	**10.9**
High	0		1.4	**16.3**
Best Estimate	0		1.2	**13.5**

Description and scale of key monetised benefits by 'main affected groups'

Reduced exposure to in-orbit third party liability claims for UK satellite operators = £690K.

Reduced insurance premiums for UK satellite operators = £12.9m.

Therefore the total benefit amounts to £13.5m.

As figures for policy option 3 are only made on a per CubeSat basis, they are not included here.

Other key non-monetised benefits by 'main affected groups'

There would be additional benefits of £98K per CubeSat launched through savings made on insurance premiums by UK satellite operators.

Increased competitiveness of UK satellite operators in global context. Benefits could feed through to satellite service consumers through lower prices.

Reduction in risk of liquidisation (and associated costs) and reduced legal fees.

Key assumptions/sensitivities/risks — **Discount rate (%)** 13

Impacts are measured over the course of 15 years instead of the usual 10 as this is the average operational lifespan of a standard satellite. The probability of launch failures and in-orbit collisions leading to third party claims, the initial number of satellites (increasing by one per year), cost of satellites including their earnings. For a full list of assumptions, see section 2, sensitivity analysis is also carried out in the evidence base.

BUSINESS ASSESSMENT (Option 1)

Direct impact on business (Equivalent Annual) £m:			**In scope of OIOO?**	**Measure qualifies as**
Costs: -1.0	**Benefits:** 0	**Net:** 1.0	Yes	OUT

Summary: Analysis & Evidence

Policy Option 2

Description: To remove the requirement for unlimited indemnity from satellite operators and reduce the insurance requirement for licensees.

FULL ECONOMIC ASSESSMENT

Price Base Year 2012	PV Base Year 2013	Time Period Years 15	Net Benefit (Present Value (PV)) (£m)		
			Low: 10.02	**High:** 13.43	**Best Estimate:** 11.70

COSTS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Cost (Present Value)
Low	0		0.1	**0.8**
High	0		0.2	**2.9**
Best Estimate	0		0.2	**1.8**

Description and scale of key monetised costs by 'main affected groups'

Increased contingent liability faced by UK Government from third party liability (TPL) claims arising from the launch or in-orbit operation of UK satellites.

The central estimate for the increase in liabilty for the government is £1.8 million over 15 years however as there is only one documented case of an in-orbit collision (with no claimants) and a very small number of launch failures, this is a very conservative estimate.

Other key non-monetised costs by 'main affected groups'

BENEFITS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	0		0.9	**10.9**
High	0		1.4	**16.3**
Best Estimate	0		1.2	**13.5**

Description and scale of key monetised benefits by 'main affected groups'

Reduced exposure to in-orbit TPL claims for UK satellite operators = £690K.

Reduced insurance premiums for UK satellite operators = £12.9m.

Therefore the total benefit amounts to £13.5m.

Other key non-monetised benefits by 'main affected groups'

Reduced financial burdens on satellite operators will likely lead to: Increase competitiveness of UK satellite operators in global context.
Increased productivity, employment and higher levels of competition through new firms.
Benefits could also feed through to satellite service consumers through lower prices.
Increased volume of business for both satellite operators.

Key assumptions/sensitivities/risks — **Discount rate (%)** 3.5

Impacts are measured over the course of 15 years instead of the usual 10 as this is the average operational lifespan of a standard satellite. The probability of launch failures and in-orbit collisions leading to third party claims, the initial number of satellites are based on UK Space Agency (UKSA) statistics and increases by one per year, cost of satellites including their earnings.
For a full list of assumptions, see section 2, sensitivity analysis is also carried out in the evidence base.

BUSINESS ASSESSMENT (Option 2)

Direct impact on business (Equivalent Annual) £m:			In scope of OIOO?	Measure qualifies as
Costs: -1.0	**Benefits:** 0	**Net:** 1.0	Yes	OUT

Summary: Analysis & Evidence — Policy Option 3

Description: The capped liability and insurance requirement waived for the in-orbit operation of any satellite that meets the criteria of a CubeSat - All figures are on a per CubeSat basis

FULL ECONOMIC ASSESSMENT

Price Base Year 2012	PV Base Year 2013	Time Period Years 2	Net Benefit (Present Value (PV)) (£m)		
			Low:	**High:**	**Best Estimate:** 0.1

COSTS (£m)	**Total Transition** (Constant Price)	Years	**Average Annual** (excl. Transition) (Constant Price)	**Total Cost** (Present Value)
Low	0			
High	0			
Best Estimate	0			**0.0001**

Description and scale of key monetised costs by 'main affected groups'

All figures are on a per CubeSat basis.
Additional contingent liability faced by Government in case of an in-orbit collision between a UK CubeSat and a third party satellite equal to £132 per CubeSat.

Other key non-monetised costs by 'main affected groups'

BENEFITS (£m)	**Total Transition** (Constant Price)	Years	**Average Annual** (excl. Transition) (Constant Price)	**Total Benefit** (Present Value)
Low	0			
High	0			
Best Estimate	0		0.05	**0.10**

Description and scale of key monetised benefits by 'main affected groups'

All figures are on a per CubeSat basis; hence not included in the costs and benefits of option 1.

Reduction in liability faced by private operators = £94.

Reduction in insurance premiums for CubeSat operators = £98K.

Other key non-monetised benefits by 'main affected groups'

Increased competitiveness of UK CubeSat operators may have knock on effects for consumers in terms of prices faced for satellite services and for society through educational or scientific advances.

Key assumptions/sensitivities/risks — **Discount rate (%)** 3.5

All figures are on a per CubeSat basis.
Impacts are measured over the course of 2 years instead of the usual 10 as this is the average operational lifespan of a Cubesat, probability of launch failures and in-orbit collisions leading to third party claims, number of satellites, cost of satellites including their earnings.
For a full list of assumptions, see section 2, sensitivity analysis is also carried out in the evidence base.

BUSINESS ASSESSMENT (Option 3)

Direct impact on business (Equivalent Annual) £m:			**In scope of OIOO?**	**Measure qualifies as**
Costs: -0.04	**Benefits:** 0	**Net:** 0.04	Yes	OUT

Evidence Base (for summary sheets)

References

No.	Legislation or publication
1	*“Liability and Risk Sharing Regime for U.S. Commercial Space Transportation: Study and Analysis”*, US DoT and FAA, April 2002
2	Registry of UK Space Objects: http://www.ukspaceagency.bis.gov.uk/assets/pdf/UKRegistryOfSpaceObjectsDecember2012.pdf
3	UKSA licensing guidance for applicants http://www.ukspaceagency.bis.gov.uk/assets/pdf/GuiForApp2010.pdf
4	Federal Aviation Administration *Liability risk sharing regime for US Commercial Space Transportation* http://www.faa.gov/about/office_org/headquarters_offices/ast/media/FAALiabilityRiskSharing4-02.pdf
5	“*Development of a generic inflatable de-orbit device for CubeSats”* Maessen, D.C., Van Breukelen, E.D., Zandbergen, B.T.C., Bergsma, O.K. 2007 International Astronautical Federation - 58th International Astronautical Congress 2007 3, pp. 1860-1870 0

Annual costs and benefits profile

	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}	Y_{11}	Y_{12}	Y_{13}	Y_{14}
Transition costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual recurring cost	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11
Total annual costs	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11
Transition benefits	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual recurring benefits	1.00	0.98	0.97	0.96	0.94	0.93	0.92	0.90	0.89	0.88	0.86	0.85	0.83	0.82	0.81
Total annual benefits	1.00	0.98	0.97	0.96	0.94	0.93	0.92	0.90	0.89	0.88	0.86	0.85	0.83	0.82	0.81

Note on discounting and price year

The numerical evidence that forms the basis of this impact assessment was collected and adjusted according to the consultation responses, in 2012. The policy will be implemented in 2013 therefore all the figures in the main body of the document are based on constant 2012 prices apart from net present values of costs and benefits which use 2013 as the base year for discounting. The annual costs and benefits shown above display a fairly level profile even when discounted; this is due to the increase in the expected number of satellites by one per year. Note that the benefits accrue to the satellite sector and costs accrue to Government.

The only other exception is the summary sheet quote of EANCB costs and benefits to business which are shown in 2009 prices and with a discount base of 2010 as per OIOO regulation.

1) Background

The 1967 UN Outer Space Treaty places an obligation on Governments to:

i) maintain a register of objects sent into space;

ii) ensure safety of operations for such space activities;

iii) bear ultimate liability for costs arising from accidental damage to 3rd parties from UK space activities.

The UK Outer Space Act 1986 ("the OSA"), provides the legal framework to fulfil these obligations and places a requirement on any UK organisation or individual launching or procuring a launch of and / or operating space objects in space to obtain a licence.

Key points of licensing under the OSA are:

- ensuring the financial health of licence applicants;
- ensuring that the activity does not pose risks to public health and safety or UK national security;
- an indemnity from the licensee to the Government against any proven 3rd party costs resulting from the activities. This is an unlimited liability on licensees;
- to help manage this indemnity, 3rd party liability insurance (to a minimum of £100 million) both during the launch and while the satellite is in operation.

The licensing system includes a technical review of the launch and operation of a satellite. This is aimed at informing the Government of any undue risks concerned with the mission. This information is used to facilitate the decision on whether or not to grant a licence or whether it should be granted subject to certain conditions. As part of its review of the OSA licensing system, the UKSA (previously BNSC) introduced improved assessments of collision risk in-orbit and for the satellite's transfer from the launch vehicle to its final working orbit. These upgraded assessments are accompanied by a deeper analysis of the design of the satellite and launcher and of safety measures in place during the mission.

2) Problem Definition

The UK is the only country to require satellite operators to take out insurance for loss and damage in the launch phase over and above that offered by the launch service provider. For in orbit issues and 3rd party liability all other countries hosting the satellite operator take the indemnity risk. Thus, the UK is the only country that requires satellite operators to insure and indemnify the Government against in-orbit risks. The insurance premiums for this can be a significant cost to satellite operators. For example, one company produced and launched a satellite at a cost of £3.5m, including launch costs and insurance. The third party liability premium came at an annual cost of £45k, or £320K over the seven year life of the satellite in question, or approximately 10% of the cost.

This additional cost, which only falls on UK satellite operators, reduces their global competitiveness in the space industry and introduces market inefficiencies. The requirements are also out of line with the Government's treatment of nuclear and oil industries which have the potential for much further reaching impacts in the event of an incident. International and sector comparisons are looked at below.

This issue was highlighted in *The Plan for Growth*, published by BIS and HMT alongside the 2011 Budget and these proposals tackle the first action for the Space industry in the growth review.

Space related third party liability claims are extremely rare; an in-orbit collision between two space craft occurred in February 2009 and was proclaimed by NASA to be the first of its kind - no liability claim has been made as a result. There have been a very small number of claims (less than 5) made relating to launch failures, none of which involved the UK. The primary reasons for such claims being rare is an extremely low probability of collision in space, coupled with measures satellites can take to further reduce this risk, and that satellites are launched via carefully identified trajectories which avoid populated areas.

With so few cases to base probabilities on, third party liability premiums for satellites are not directly related to a 'risk multiplied by impact' approach that is commonly seen in other insurance markets. An FAA report (2002) found a basic agreement that for low probability but high impact events the premiums are often set high to cover the lack of business volume that would otherwise be relied on to generate capital to cover pay-outs. This demonstrates that the premium satellite operators face in the private insurance market is inflated by this information market failure.

UK companies argue that Government requirements are onerous and place them at a disadvantage. Companies are now structuring work to take licences in other countries. They also argue that the unlimited indemnity is effectively meaningless because, if enforced, many companies would simply go bankrupt such that the government is de facto bearing the risk anyway.

In its present form the outer space act represents a government failure as it requires satellite operators to insure the government against the unlimited indemnity set by the UN and take out insurance during the in-orbit phase. The UK is the only country that requires this extra burden on the licensee which is likely to have several results for the sector:

- Reduced competitiveness internationally: If UK firms face higher costs to satellite operation than foreign firms, their ability to compete in global markets is reduced. Given the highly tradable/ global nature of the space industry and the high price elasticity of demand (explained more fully later) the UK space sector could be losing large volumes of business to foreign competitors.
- Firms are less likely to enter the market: Higher costs act as a barrier to entry to a market; as a result there will be less employment and less competition in the sector. This in itself is believed to lower innovation and international competitiveness.
- Firms that already exist in the market will have less revenue to re-invest in research and development, and training; reducing the UK space sector's productivity in the future and inhibiting spillover benefits for the rest of the economy.
- Consumers will face higher cost and lower supply than they would have under a fully functioning market, thereby reducing their utility.
- This reduction in business activity will have adverse impacts on the insurance sector as less satellites will be launched and therefore less satellites are insured.

SECTOR COMPARISON

The UK policy for satellites is inconsistent with policy in the nuclear and off-shore oil and gas industries, both of which have capped liability for private operators.

Regarding indemnity requirements in the nuclear power industry, the UK is party to the Paris Convention on Third Party Liability in the Field of Nuclear Energy. This imposes a number of obligations on nuclear operators including strict liability and compulsory financial security (usually insurance) to cover that liability. To ensure that the liability is insurable it is capped. In the UK, operators are liable to pay compensation up to £140m per nuclear incident.

The UK is also party to the Brussels Convention supplementary to the Paris Convention. This provides for a mechanism where government funds are used in the event of catastrophic accidents where the operator's liability is insufficient. These funds are also capped and HMG is liable for excess damages up to approximately £250m.

These conventions have recently been revised with increased compensation amounts. When these enter into force the operator will be liable for €700m under Paris, with a total compensation under both conventions of €1,200m per incident.

In the off-shore oil industry, liabilities are managed through an organisation called OPOL (Offshore Pollution Liability Association). OPOL was introduced by the oil industry and envisaged as an interim measure and alternative to the 1976 Convention on Civil Liability for Oil Pollution Damage, which has never come into effect. In 1983, HMG accepted that the principles and aims of the Convention were best achieved through OPOL and HMG recognises that the Agreement meets the requirements for the availability of funds to deal with oil pollution as set out in the Petroleum (Production)(Seaward Areas) Regulations 1988 model clause 23(9).

OPOL is set up as a UK limited company, which administers a voluntary liability compensation scheme to which all UK offshore operators are parties. The agreement also covers all coastal EU states, Norway, Isle of Man and the Faroe Islands. The OPOL agreement requires all signatory operators to accept liability (with the exception of incidents caused by war, terrorism etc.) for pollution damage and the costs of remedial measures arising from a spill from their facilities up to US$120m.

INTERNATIONAL COMPARISON

An excessive UK licensing regime for the launch and operation of satellites threatens the transfer of responsibility of key stages in space projects to sister companies or competitors in other countries. This is a concern because loss of operational business will impact on important downstream market opportunities.

Most launch capable countries require third party liability insurance for the launch, and this is imposed on the launch service operator and not satellite operators or customers. There is no requirement in any other country for third party liability insurance for the duration of the life of the satellite, although France is planning to introduce legislation that will place a limited liability on operators, to be managed how the operator sees fit.

The tables below give an overview of insurance and indemnity requirements in some other countries.

Table 1: Comparison of insurance requirements for satellite operators and launch service providers.

Jurisdiction of Satellite Operator	Amount of Insurance Required of Satellite Operator	Amount of Insurance Required of Launch Service Provider	Throughout Ops. Life Third Party Liability Insurance Required by Jurisdiction
USA	USD 0	USD 10M – USD 275M (approx) based on mission by mission analysis of Maximum Probable Loss	No
RUSSIA	USD 0	USD 100M	No
FRANCE	Limited liability on operator planned – insurance not required.	€60M (approx)	No
CHINA	USD 0	USD 100M	No
UK	£100 M each for launch & in-orbit phases	N/A	Yes

Table 2: Comparison of indemnity requirements

Launching State	Indemnity Required from Satellite Operator	Indemnity Provided by Launching State to Launch Service Provider	Insurance/ Indemnity Extended to Customers
USA	None	Yes, up to USD 1.5 billion in excess of insurance	Yes
RUSSIA	None	Yes, unlimited in excess of insurance	Yes
FRANCE	None	Yes, unlimited in excess of insurance	Yes
CHINA	None	Yes, unlimited in excess of insurance	Yes

UK	Unlimited indemnity provided by Satellite Operator to HMG	N/A	N/A

OPTIONS

To rebalance the situation, the UKSA proposal is to either:

- 1) Implement proposal 2 and 3 below or;
- 2) Remove the unlimited indemnity under s.10 of the Act from satellite operators to the Government and instead cap private satellite operator's liability at €60m for the launch and in-orbit phase of the mission. The insurance required for a license would be reduced in line with this, from £100m to €60m;
- 3) Waive the capped liability and insurance requirements for the in-orbit operation of CubeSats.

The government recommends supporting option 2 only.

RISKS AND ASSUMPTIONS

The proposals entail monetised and non- monetised costs and benefits. The process of valuing these costs and benefits is a somewhat inexact one as both the frequency and consequences of an adverse event are uncertain, and operations in space have not been occurring for long enough for good distributions of the risks to exist.

Key Assumptions

i. Number of UK satellites in orbit at any one time: 45 (9 Low orbit, 2 Medium orbit, 34 High orbit) (Source: UKSA). The calculations assume that there will be an annual increase by 1 in the number of UK owned satellites in operation at any one time, split by the probability of this being a GEO, MEO or LEO.

ii. Average useful life of a satellite: 15 years: based on the average lifetime of GEO, MEO and LEO satellites weighted by the proportion of each type in orbit over the last 10 years (Source: UKSA).

iii. Probability of a launch failure: 10^{-2} (Source: Unpublished QinetiQ report into risk and insurance issues for UKSA).

iv. Probability that the satellite owner would face 3rd party liability in the event of a launch failure: 0.1. (Source: as above. Note the low probability is due to the fact that satellites are launched via carefully identified trajectories avoiding populated areas, normally over the sea or desert. The sea covers approximately 70% of the earth).

v. Probability of collision over the useful life of an 'average' satellite, without any enforced safety assessment: $8.47*10^{-5}$

This was the most difficult factor to assess, as each individual orbit has a different collision risk, and the risk is also affected by the satellite's design and control systems, its fuel load, and the degree of supervision exercised by the satellite's owner. One estimate of average risk was a consultant's report commissioned to Qinetiq as part of the review of the Act in 2005, which identified that the probability of collision risk over the effective life of the satellite at the point of first assessment was normally in the range of 10^{-4} and 10^{-6} [1]. Calculations in Annex 2 give a probability of collision of $7.7*10^{-6}$ per year for a standard satellite platform in Low Earth Orbit (LEO) at 600km altitude. Based on space density throughout LEO, this is a reasonable average to take that region. The Registry of UK Space Objects suggests this is also a reasonable average altitude for satellites in LEO, however the majority of UK satellites are in

[1] Figures taken from a Moreton Hall Associates report *Review of the licensing regime operated by BNSC under the Outer Space Act 1986*. This report is commercial in confidence and has not being published.

GEO, at ~35,000km altitude. As the space density at LEO is higher than at GEO, using this risk for all satellites can be considered a conservative estimate. Combining this figure with the average useful life of a satellite gives the probability of collision above. This IA does not account for the likely increase in space density that will be seen over time.

vi. Reduction in probability of an in-orbit collision due to OSA mandated safety review: 20%.

There is no hard evidence for this. The collision risk above is based on objects randomly orbiting earth. The UKSA, however, requires all satellite operators to complete a thorough mandated safety assessment, the details of which are in annex 3. Given the coverage of this assessment it seems reasonable to assume that there will be a significant reduction in collision risks as a result. There is not, however, enough evidence to be confident about a figure. In this impact assessment, a 20% reduction is assumed. Whilst no specific sensitivity analysis is carried out around this figure, there is analysis considering a far higher degree of in-orbit collision risk which is conservative enough to sufficiently cover this assumption as well.

vii. Value of an average satellite: £200 million if on high or geosynchronous orbits £20 million if on low to medium orbit, based on density of satellites in space the average value of a satellite is £150 million (Source: estimate from Inmarsat and the consultation).

viii. Cost of launch insurance for £ 100 million cover: £120,000 - £150,000 (Source: estimate from Aon).

ix. Average cost of in orbit insurance (£100m cover) per satellite per year: £75,000 (Source: estimate from Aon).

x. Reduction in insurance premium for reduced cover of £50m: 20% - 30% (Source: estimate from Aon)

xi. Discount rate: 3.5% (Green Book).

xii. Size of third party liability claims: Historical evidence is scarce due to the relative infrequency of such incidents. For third party claims arising from launch failure, all past incidents have been below the current and the proposed insurance thresholds, although it is feasible that this will not be the case in future incidents, especially if an incident involves the loss of life. The feasible upper limits are, therefore, extremely high but it is not possible to construct a robust distribution of what the size of claims may be. As such, this IA only attempts to calculate the increase in liability arising from the proposed changes to insurance/liability thresholds. For in-orbit collisions, the size of third party claims is based on the average value of a satellite and an estimate of its expected life time earnings. This is estimated to total £350m. It is noted in the evidence base that the UKSA mitigates the risk of both launch and in-orbit incidents through the thorough safety checks necessary to gain a license to launch and operate a satellite.

xiii. The impact on the insurance sector. The benefit to satellite operators experienced through lower premiums can be classified as a transfer away from insurance companies. However, insurance companies' revenues are likely to be more than offset through the increase volumes of satellites that will require insurance. This is because the outer space act is currently restricting the space sector, impeding full market efficiency. This proposal will help increase output and decrease price by reducing this burden. Research has also shown that there is a high level of price elasticity of demand for space products; as a result a small drop in price should yield large increases in revenue. This is discussed further on page 16. For this analysis we make the cautious assumption that the overall revenue is offset for the insurance industry (zero net effect).

3) Policy Option 2

Under this option, s.10 of the OSA would be amended to remove the indemnity requirement that is causing unnecessary burden on space operators; thus constituting a redistribution of liability away from satellite operators to the government. For each license application, a risk assessment will be performed to consider the potential risks posed by the mission and a commensurate level of insurance cover will be determined. In the majority of cases of missions employing established launchers, satellite platforms and operational profiles, the insurance cover would be limited to €60m, in line with international competitors (see table 1 for details of the requirements made in other countries). The UKSA will retain the option to increase the insurance and liability cap for higher risk missions. As with the current situation, the UK Government would be liable for covering the remainder of any third party liability claims pursuant to the UN Treaty on Outer Space arising from the activity of private satellite operators.

In line with this, the condition of licensing for third party liability (TPL) cover would be reduced in line with the reduction in liability, typically from £100m to €60m for the launch phase and the duration of the mission. As it is expected that cases in which the liability/insurance is higher than €60m will be very rare. This impact assessment works on the assumption that all cases will be capped at this amount.

Although this proposal would appear to pose a heavy burden on HMG, the likelihood of third party claims being made, either due to a launch failure or an in-orbit satellite failure is extremely small. Moreover, in practice, under the current regime, and in case of large claims, companies may have to go bankrupt and the UK Government would in any case face a substantial liability. It is thus believed that the situation suggested would reduce uncompetitive regulation and reduce the burden on private satellite operators with minimal additional risk to government over that which it already has.

It should be noted that this proposal contains both policy and legislative elements – the proposal to adjust the insurance requirement is a policy option with no legislative implications as this requirement is not stated in the Outer Space Act. Adjusting the liability section of the OSA, however, would need secondary legislation, being achieved through a Legislative Reform Order. As this process could take up to a year longer to implement than the policy decision, it is possible that different elements of this proposal will be implemented at different points in time.

This policy option contains costs and benefits which can be monetised along with some which can not. For companies, the impact will be a reduction in the contingent liability they would face in the case of an incident which led to third party liability claims along with a reduction in the cost of insurance premiums. For the Government there would be an increase in the contingent liability it faces. There may also be wider impacts on the competitiveness of UK satellite operators and service deliverers.

The following section explores the three monetarised benefits for satellite operators: **third-party liability *(2)***, **launch insurance *(3)*** *and* **in-orbit insurance premiums *(4)***. The monetarised costs for government i.e. the increased liability from **launch *(1)*** and **in-orbit *(2)*** incidents are also included here. These costs and benefits are then combined on page 14/15 to show the discounted total and net impacts of this policy. The wider non-monetarised impacts are considered on page 15.

Third party liability claims

This proposal entails a shift in liability for TPL claims from satellite operators to HMG. Claims could arise from launch failure incidents and from in-orbit collisions. In each case the value of the risk can be calculated using a number of assumptions on the value of the satellite, the size of the claim and the probability of an incident.

Impact on TPL claims from launch failure ***(1)***

The expected third party liability (TPL) cost from launch failure (EC_l) is computed as the cost to third parties from launch failure (C_l) multiplied the probability of facing third party liability as a result of launch failure (p_l):

$EC_l = C_l \times p_l$

The probability of facing third party liability as a result of launch failure p_l is the product of the risk of launch failure (equal to 10^{-2}, see assumption (iii) in section 2) by the probability that the satellite owner would face 3rd party liability in the event of a launch failure (equal to 10^{-1}, see assumption (iv) below). The product of these two quantities is equal to: $10^{-2} \times 10^{-1} = 10^{-3}$.

The cost C_l is the expected cost to third parties from launch failure. This varies between £0, if no damage occurs, and some positive quantity. There is very little historical evidence from which to yield an estimate as to what the full cost of a third party liability could be expected to amount to. A 2002 report by the Federal Aviation Administration (FAA) cites a number of commercial launch failures in China and Russia since 1995 that resulted in third party claims with payouts of no more than $10m. Failures in these countries are more likely to result in third party claims as they are more likely to launch in-land, whereas most other countries launch over the sea or unpopulated areas such as deserts. UKSA licensing examines all safety aspects of the launch so as to further minimise the risk to third parties.

As such, the cost of such an event is unlikely to exceed the current £100m insurance and historically even the proposed €60m insurance level has not been passed. A lack of historical events makes it difficult to score the full additional cost that Government will bear as a result of this proposal. Instead, we calculate the increased social burden resulting from the changing insurance requirements. In the event of a very large claim, it is likely the private company would not be able to pay it and the Government would have to be liable anyway.

The following calculations, therefore, consider the increased contingent liabilities the Government faces as a result of the insurance requirement falling from £100m to €60m. This is approximately £50m under the exchange rate of 0.81 on 18 December 2012 (source www.xe.com).

The additional cost per launch failure which leads to a third party claim compared with the status quo is, therefore, between £0 and £50m.

The increase in the expected TPL cost from launch failure is thus between £0 and $10^{-3} \times$ £50m (therefore between 0 and £50,000 per satellite) with a central estimate of £25,000 per satellite.

Annualised over 15 years of satellite lifetime, for a satellite fleet starting from 45 UK satellites and increasing annually by 1, using a 3.5% discount rate, this gives **expected additional costs for HMT** of between £0 and £2m, with a present value central estimate of **£1m.**

Impact on TPL claims from in-orbit collisions ***(2)***

The cost of in-orbit collision is determined by the value of third party satellite plus the loss of earnings from it minus the insurance cover.

The insurance cover currently amounts to £100m, so firms are liable for the excess of all claims above that amount. Under this proposal, private companies would be liable only for the first €60m, which would be covered by insurance, or £50m based on the above exchange rate. This exchange rate is liable to change constantly and sensitivity analysis will be carried out around this rate. The €60m cover is consistent with the standard insurance cover offered by Arianespace for launches.

The additional impact of this proposal is that firms will benefit as they will no longer face the expected cost of third party liability claims made against them. This equates to a saving of the expected value of all claims above £100m, net of the £100m currently covered by insurance. There will, however, be an additional cost to Government, who will become liable for all third party liability claims over €60m.

The average value of a satellite is around £150 million (calculated as a weighted average of the value of satellites given in assumption (viii) below, with weights equal to the number of satellites in each orbit, as per assumption (i)).

The annual earnings from a satellite vary greatly depending on what its purpose is and how long is left of its operating life. Avanti's Hylas satellite is expected to earn around £400m over the course of 15 years. If we assume this is the average earning from a satellite and further assume that at the point of collision it is half way through its operational life, the lost earnings amount to around £200 million.

The **risk** of in-orbit collision is determined by the probability of such an event happening. Based on the figures in Annex 2, this is estimated to be $8.47*10^{-5}$ over the lifetime of the satellite. It is assumed that this risk is reduced by about 20% as a result of the OSA mandated safety review.

The product of these two elements, over the average satellite lifetime of 15 years and for a satellite fleet of 45 satellites (increasing to 59 satellites over 15 years and using a 3.5% discount rate) gives the **expected benefit to private satellite operators** arising from this proposal, as **£690k** in present value terms over the 15 year period or £46K annually**.** This benefit is realised through a reduction in expected costs arising from third party liability claims.

The increase in **liability for the Government** would amount to **£829k** in present value terms, or £55K annually. The full contingent liability of £55K per annum would not need to be added to the Government's declarations, as explained below.

Sensitivity Analysis

This estimate is somewhat sensitive to the assumptions made above. Considering a much higher level of earnings of £1bn per satellite, the expected cost would amount to around £3m, or £203k annually.

Using a much more conservative estimate of the risk of in-orbit collision, increasing it to 10^{-4}, the increase in contingent liability is £1.4m over the 15 year period or £92K annually for average satellite earnings of £200m.

These estimates are, however, extremely conservative anyway. Claims can only be made if the incident was the provable fault of one particular party. The methodology used here assumes that every in-orbit collision is the provable fault of the UK owned satellite. This may not be the case as fault could be extremely difficult to apportion. It would seem reasonable to assume that the actual contingent liability in the case of an in-orbit collision between two satellites would be half the above amount, on the basis that the fault would be just as likely to lie with the other party involved in the collision. We do not, however, account for that here.

Exchange rate sensitivity analysis

These figures are estimated on the basis of £50m. The insurance, however, is for €60m, and so the sterling value is subject to change with exchange rates. If the exchange rate shifted such that €60m equated to £35m, the cost to government would increase to £870K, an increase of £41K. If the exchange rate was such that €60m equated to £65m the equivalent cost to government would be £787K a reduction £42K.

This results because the insurance cover that a satellite operator is required to pay falls relative to the value of a satellite; therefore the government obligation to cover the gap between the insurance value and the actual value of the satellite liability, increases.

Expected Government liability for third party loss

The expected third party liability cost following an in-orbit collision is given by the cost of in-orbit collision by its risk as calculated above.

Currently, the UKSA requires satellite operators to take out insurance of £100m and so the amount that needs to be indemnified is that which is in excess of £100m. It should, however, be noted that if the operator is unable to pay for this, the UK Government will still be liable under the terms of the UN Treaty. This liability is, therefore, currently included in the contingent liabilities as reported to HM Treasury. With the new lower cap of €60m, and assuming that the risk of collision is the conservative 10^{-4}, the **additional** contingent liability is £9K annually – the difference between the current £100m insurance requirement and the new €60m cap. Based on similar calculations, a similarly small liability would also arise on launch incidents.

The same exchange rate sensitivity as above would apply to this figure.

Insurance premium impacts

A reduction in the insurance requirements entails benefits from private satellite operators through cheaper insurance premiums.

The reduced cost for launch insurance ***(3)***

The cost of launch insurance for £100 million is approximately £120K to £150K per satellite. Reducing the insured sum will not normally lead to a proportionate reduction in the premium: insurance experts reckon that reducing the requirement by 50% would reduce the premium by 20% to 30%, since underwriters will seek a minimum premium before taking on the risk to their capital.

The benefits from the reduced cost for launch insurance are computed as present value (PV) of the reduction in the insurance premium for 45 (to 59) satellites over 15 years. Based on the above ranges, the reduction in the premium would therefore be between £24K and £45K, with a central estimate of £34K (£135,000 x 25%).

The PV **benefits** from the **reduced launch insurance** range between £1m and £1.8m, with a central estimate of **£1.4m**.

The reduced cost for in-orbit insurance ***(4)***

The cost of in-orbit insurance is equal to £75,000 per year per satellite on average. Again we make the assumption that reducing the requirement for insurance from £100 million to €60 million will reduce the premium by 20% - 30%.

The benefits from the reduced cost for in-orbit insurance are computed as present value of the reduction in the insurance premium for the 45 (to 59) satellites over 15 years.

The PV **benefits** to satellite operators from the **reduced in-orbit insurance** range between £9.2m and £13.8m with a central estimate of **£11.5m**.

Combined total benefits and liabilities of the proposal

The Total combined benefit for satellite operators

A) The reduced exposure to TPL in-orbit claims is £690K (based on the reduced liability for costs incurred over and above the £100m insurance cover) ***(2).***

B) The benefits from reduced launch insurance are estimated to be £1.4m (based on 34K saving per launch) ***(3).***

C) The benefits from reduced in-orbit insurance are estimated to be £11.5m (based on a 75K premium per satellite per year for in-orbit insurance) ***(4).***

Therefore the **best estimate of total benefits of this proposal amounts to £13.5m**.

The lower-band benefit estimate from combining insurance premiums (£10.2m)*(3+4)* and reduced TPL in orbit-liability (690k) *(2)* is £10.9m.

The upper-band benefit estimate from combining insurance premiums (£15.6m)*(3+4)* and reduced TPL in orbit-liability (690k) *(2)* is £16.3m.

The increase in total government liabilities

D) The increase in expected government liability from launch failure TPL claims is £1m (based on the extra cost over and above the insurance taken out by satellite operators from an expected claim of 25K per launch) ***(1).***

E) The increase in government liability from in-orbit liability is £829K (based on the increased liability from costs incurred over and above the new £50m threshold of insurance held by operators) ***(2).***

Therefore the present value for total increase in expected **government liability** over 15 years is **£1.8m.**

The lower-band cost estimate from the impact of launch failure (£0)*(1)* and the impact of in-orbit collision (£829k) *(2)* is £0.8m.

The upper-band cost estimate from the impact of launch failure (£2m)*(1)* and the impact of in-orbit collision (£829k) *(2)* is £2.9m.

The Net benefit arising from this proposal (1)(2)(3)(4)

The resulting central estimate taking into account central benefits (13.5) and central costs (1.8) is a present value net benefit of £11.7m.

The lower-band net benefit arising from the total benefits (£10.9) and the total costs (£0.8) is £10m.

The upper-band net benefit arising from the total benefits (£16.3) and the total costs (£2.9) is £13.4m.

**Note that these figures may not add up exactly due to rounding, numbers in italics refer to the sections above in the methodology.*

Wider Impacts

Behavioural impacts

It is possible that the transfer of third party liability risk away from private operators to Government may affect the behaviour of those firms. As with the purchasing of insurance, the removal of indemnity raises the prospect of moral hazard; private satellite operators have less incentive to mitigate the risk of an incident which could lead to third party claims against them. If this were to happen, the risk of an incident could increase, thereby increasing the expected cost to Government.

In this case, however, it is likely that this risk of moral hazard will be mitigated through two channels. Firstly, all private operators applying for a license will be required to pass stringent safety tests, as is the current situation. Secondly, the UKSA will retain the option to increase the insurance requirement and liability cap for higher risk missions, meaning the firms will retain an incentive to reduce risks as far as is cost-efficient in order to lower their insurance premiums.

Bankruptcy

Under certain circumstances, the proposal might also bring higher benefits to the UK compared with the status quo. More precisely, in case of a large claim and subsequent bankruptcy of the satellite firm, liquidation of the firm's assets might prove lengthy and costly. This would lead to significant losses of the firm's asset value, and a lower contribution to cover the third party liability claim. Under the proposal, HMG would step in to cover the total claim and, under similar circumstances, liquidation costs would not be incurred.

From the distributional point of view, the proposal has some effects, which are difficult to quantify but can be summarised as follows:

When HMG steps in to cover a third party liability claim, it does so at taxpayers' expense;

if the firm is instead liable for the claim the cost of the incident is borne by the private sector - in case of bankruptcy, the cost would fall on the firm's employees, the investors in the firm's equity and other firms that are part of the industry supply chain, as well as the Government. As in the case of a bankruptcy resulting in an inability to pay 3rd party costs the Government would become liable under the UN Outer Space Treaty.

It is expected that the change in the insurance requirements proposed could have significant impact on the UK space industry. Lack of detailed industry level data makes a quantitative analysis of the impact difficult to carry out. Qualitative analysis and some case studies, however, are available.

Competition

Lower launch insurance requirements could significantly reduce the production cost for satellite manufacturers and licensees, as in the example set out in section 2. This would boost their competitiveness and ultimately result in higher production and sales.

Reducing the requirement for in-orbit insurance would also help restore competitiveness of UK satellite operators and reduce prices for satellite services. The price elasticity of demand for satellite services is significantly high, in particular for broadcast and telecommunication services (Goolsbee and Petrin (2004) for example, estimate an own-price elasticity of demand for Direct Broadcast Satellite services of around -8. This means that for any 1% decrease in price (as a response to the reduced insurance premiums), demand for these services increases by 8%), lower prices would lead to an increase in demand and therefore in the turnover of these companies.

Although the benefits deriving from the proposed amendment of the OSA will initially accrue mainly to UK businesses, consumers will ultimately benefit from a reduction in prices for satellite services.

Impact of insurance companies

The proposed changes to the outer space act will also have consequences for firms that insure satellite operators. As already noted due to government requirements and information market failure the insurance premiums that licensees pay are above the actual expected value of the liability. Insurance companies may not be benefiting from this as the extra burden on satellite operators increases the chance of bankruptcy and reduces the overall profitability of the sector.

The reduction in insurance premia and liabilities will also constitute a less than 1:1 reduction in insurance revenue (approx a 20-30% reduction) and as one insurance company noted the fact that high costs have hindered growth in the space sector, when combined with a high price elasticity of demand for satellites, they reasoned that they would actually increase their revenue from increased satellite launches and UK space activity. When combined it is not unreasonable to say the negative impact of this policy on the insurance sector will be small, and may in fact be positive.

<u>Company Case Study:</u>

SSTL

SSTL is a UK manufacturing company that competes in a specialised international market for small satellites. In-orbit insurance requirements can add up to 10% to the cost of this type of satellite (typically quite low), leaving this company vulnerable to international competitors.

The in-orbit insurance requirements mean that SSTL cannot currently afford to offer the in-orbit service that many of its potential customers ask for. Moreover, although this market segment represents only about 25% of SSTL orders, it accounts for approximately 50% of the value of the company's bids, as it represents larger value missions.

It is estimated that, if the insurance requirement were relaxed, the company would be able to deliver its satellites in-orbit.

Net Benefits

A summary of the centralised estimates of the range of monetised costs and benefits from the analysis above is contained in the table below, with the ranges around them in parentheses, which also highlights the net benefits:

Table 3: Costs and benefits of policy option 2

Total benefits central estimate (lower bound, upper bound)	**£13,547,539** **(£10,853,656 £16,302,646)**
Total costs central estimate (lower bound, upper bound)	**£1,849,067** **(£828,657, £2,869,478)**
Net benefits central estimate (lower bound, upper bound)	**£ 11,698,472** **(£10,024,999 , £13,433,169)**
Benefits: Costs ratio (lower bound, upper bound)	**7.3:1** **(13.1:1, 5.7:1)**

4) Policy Option 3

Under this option, the capped liability and insurance requirement would be waived for the in-orbit operation of any satellite that meets the criteria of a CubeSat, assuming they can demonstrate scientific or educational merit and that they adhere to the space debris mitigation guidelines which propose a 25 year maximum orbital lifetime. The liability and insurance requirement would remain for the launch of the mission.

Although this appears to pose a heavy burden on HMG, the risks arising from the operational phase of a CubeSat or similar mission are significantly reduced compared to a standard satellite.

There are no reliable estimates as to how many UK owned CubeSats will be launched in the future, either with or without this policy. As a result, all estimates in this assessment are on a **per CubeSat** basis only. Another result of this uncertainty is that CubeSats have not been accounted for in policy option two, which assumes a constant, but low, increase in the number of UK owned satellites over the period under assessment. All costs and benefits listed in this section are as compared to the status quo.

<u>What is a CubeSat?</u>

CubeSats are small, fully functioning satellites with a standard size of 10x10x10cm and weight in the region of 1kg. A standard CubeSat is often referred to as a '1U' CubeSat, meaning one unit. They are scalable in 1U increments and '2U' and '3U' (30x10x10cm) have been built and launched. A 3U CubeSat is the maximum size that would be allowed under this policy and the maximum weight would be limited to 5kg, including payload.

CubeSats contain all the subsystems expected of a satellite and are normally comprised of off-the-shelf components together with a modestly dimensioned payload. Their small size and low complexity make them both inexpensive and able to be launched on a rapid timescale. The CubeSat platform has attracted a lot of interest worldwide and the USA and Japan already have dedicated national educational programmes.

Last year, the UKSA announced its own programme to design and launch a CubeSat, with the Minister for Universities and Science stating that "Britain's first CubeSat will bring major benefits to the UK space industry."

Information regarding the current number of CubeSats in orbit, and the expected growth of this figure, is scattered and unofficial. It seems that the best catalogue of current satellites in orbit is "Gunter's Space Page", which has a section dedicated to CubeSats and includes all known launches (http://space.skyrocket.de/doc_sat/cubesat.htm). This suggests, inline with other sources (http://cubesat.ifastnet.com/forum/viewtopic.php?f=11&t=68), that there are currently around 40 CubeSats in orbit.

Growth in CubeSats has been rapid (http://www.clyde-space.com/resources/cubesats) but there are no reliable estimates of how fast this market will grow globally, let alone in terms of UK owned CubeSats which are an almost entirely new concept. As such, analysis here is carried out on a per CubeSat basis.

The vast majority of CubeSats launched so far have been for educational purposes, built by universities. There have also been a number of scientific CubeSats built. As technology has miniaturised, CubeSats have become viable platforms for commercial purposes as well.

<u>Case Study</u>

Clyde Space provided the following text and data:

Based on market analysis by two independent organisations; the small satellite market is currently estimated to be worth between $600m and $1.1bn. Due to being an emerging market, CubeSats are still a small proportion of this market at between $30m-$40m, but the growth rate of the CubeSat market is in the order of 100%+ compared to a 10%+ demonstrated by the small satellite market in general. We expect the CubeSat market to have a value of between $200m and $500m by 2015.

What is the reduction in risk during the operational phase of a CubeSat?

For full details and calculations, see risk assessment at Annex 2.

Due to their comparatively small size, CubeSats carry less risk during their operational life. Compared to a standard satellite platform in Low Earth Orbit (LEO), in which CubeSats would operate, the collision risk over the course of a year is reduced by a factor of approximately 30. It should be noted that whilst CubeSats have a relatively short operational lifespan, of 1-2 years (compared to 8.5 years for standard platforms in LEO), they may stay in orbit far past their operation as they lack the ability to propel themselves out of orbit.

It is expected that all low Earth orbit (200km – 2000km altitude) satellites are orbited such that they de-orbit within a 25 year timeframe. Currently the UKSA expects satellites to remain insured for their mission and until they are safely located (de-orbited).

Most larger satellites have the ability to propel themselves to a graveyard orbit once their mission ends and so this is not an issue. The size of CubeSats, however, means they can not propel themselves, and other deorbiting methods are in their infancy and not installed on CubeSats as a matter of common practice. This means that even though CubeSats have a shorter mission lifespan, they may remain in orbit for many years past that.

The length of time in orbit depends upon the altitude of the orbit (there are other factors which affect the natural de-orbit time, such as the solar cycle, but these are not controllable). It is estimated in "D*evelopment of a generic inflatable de-orbit device for CubeSats"* that at an altitude of 700km a CubeSat would naturally decay in 25 years. Lower orbits, however, would decay quicker. Most CubeSats orbit at an altitude of between 350 and 600km.

Given the high annual insurance burden the current regime places on satellite operators, it seems likely that it would not take long for cost-effective devices to be commonly available to CubeSat operators. In this case, CubeSats' lifespan in orbit would reduce considerably, having an impact on the costs and benefits.

Given most CubeSat missions operate for one or two years, it is sensible to assume that under the current regime, in which operators would have to insure their space craft for each year in orbit, they would opt to install a de-orbiting device which would cause the CubeSat to leave orbit after two years, thus reducing the insurance burden.

Assuming an average of two years in orbit for CubeSats, the average probability of collision for a CubeSat over the course of its in-orbit lifespan is $4.8*10^{-7}$. Allowing for the increase in safety from the enforced safety assessment this falls to $3.84*10^{-7}$.

Further reductions in risk are found through the reduced consequence of a collision. When satellites collide with other objects in orbit they typically break up, releasing smaller fragments into orbit as a result. Under the UN Outer Space Treaty, states are liable for costs arising from accidental damage to 3rd parties – this may include damage caused by these fragments released after a collision.

Due to their smaller mass in comparison to larger satellites, the number of fragments released in a collision with a typical space object is estimated to be 10 times fewer for CubeSats (see Annex 2 for calculations). This indicates a reduced risk of such fragments colliding with 3rd party satellites, although the reduction in risk may not have a one-to-one relationship with the reduction in the number of fragments.

Costs and Benefits

*Impact on TPL claims **(5)***

This proposal entails a shift in liability for TPL claims from satellite operators to HMG for claims arising from in-orbit incidents involving CubeSats colliding with third party spacecraft. As in the previous option, the value of risk can be calculated from the value of the third party satellite, the size of the claim and the probability of an incident.

As above, the methodology used here assumes that every in-orbit collision is the provable fault of the UK owned satellite. This may not be the case and, as such, the figures here could be deemed a conservative estimate of the costs. Furthermore, the methodology assumes that every collision is with an operating third party satellite. The calculations for the probability of a collision, however, are based on collisions with any object in orbit. The vast majority of tracked space debris, however, is just that – debris. The likelihood of a collision with another satellite would be considerably lower.

The additional impact of this proposal is that firms will benefit as they will no longer face the expected cost of third party liability claims made against them. As before, this equates to a saving of the expected value of all claims above £100m, net of the £100m covered by insurance. The Government takes on an equivalent amount of risk.

The cost is assumed to be the same as before; with the average value of a satellite being around £150 million with average lifetime earnings lost of £200m.

As outlined above, the in-orbit lifespan probability of a collision for a CubeSat is $3.84*10^{-7}$.

The present value expected costs of a collision is, therefore, £350m*$3.84*10^{-7}$ per CubeSat. Once the reduction in risk provided by the mandatory safety assessment is taken into account, this gives an expected (non present value) cost to third parties of an in-orbit collision £48 per annum. The much lower cost compared to that of policy option 2 is due entirely to the lower risk of a collision due to the relative size of a CubeSat and a standard platform.

With the current £100m insurance cover, the expected liability for CubeSat operators, and **the expected benefit to private CubeSat operators** arising from this proposal**,** is **£94** in present value terms, or £47 per annum per CubeSat.

The cost to Government would be the full cost to third parties, as no insurance would be required under this proposal. Therefore, the **PV expected cost to Government** arising from this proposal is **£132,** or £66 per annum per CubeSat. Of this, £38 per CubeSat would be an additional contingent liability that would have to be reported to HMT accordingly (for the same reasons as explained in section 3).

*Lower Insurance premiums for UK satellite owners **(6)***

TPL premiums for satellites are not directly related to a risk * impact approach that is commonly seen in other insurance markets. An FAA report (2002) found a basic agreement that for low probability but high impact events the premiums are often set high to cover the lack of business volume that would otherwise be relied on to generate capital to cover pay-outs. As such, companies taking out insurance on small satellites are unlikely to face proportionately lower premiums. Indications from the insurance market are that the cost of £100m of in-orbit third party liability insurance for a CubeSat would be around £50K for one year of cover. The premium levels are largely driven by the minimum premium chargeable for the significant amount (£100m) at risk. There may be opportunity to reduce the premium if there were multiple satellites included on the same insurance package.

Assuming that this is the per-CubeSat annual insurance that owners would face, the saving for each CubeSat would be £50K per annum for every year the satellite was in orbit. In present value terms, this equates to **£98K per CubeSat** over the course of 2 years or £49K per annum. This is a benefit which accrues to CubeSat operators.

<u>Sensitivity Analysis</u>

The figures in this analysis are based on a number of assumptions with much uncertainty around them. In-orbit collisions are extremely rare, and whilst the formula used here to create the probability of collision is the established technique, it is far from perfect. For example, it assumes that all objects are spheres, which is clearly not the case for CubeSats. Where possible, the assumptions have erred on the side of caution, such as by assuming all collisions will be the fault of the UK-owned satellite. It also assumes that all collisions will be with other satellites. This is clearly not the case as most space debris is not operational satellites (although the fragments released by such collisions may go on to collide with satellites. The additional benefit that CubeSats hold over standard platforms, that they release fewer fragments following a collision, has not being quantified.

Considering the higher loss of earnings of £1bn per satellite, the equivalent figures are a £396 benefit to CubeSat operators per CubeSat and a £434 cost to Government per CubeSat.

Using a much more conservative risk of in-orbit collision of 10^{-6} the estimated figures increase to a £942 benefit per CubeSat over the two years it is in orbit with an equivalent cost to Government of £1.3K.

<u>What are the other benefits to the UK?</u>

The nature of CubeSat missions, their rapid turn-around and low cost mean they lend themselves particularly well to education and outreach. However, by exploiting advances in miniaturisation, CubeSats are increasingly being employed in commercial and scientific arenas. CubeSats also provide a highly accessible vehicle for the public to engage. Public outreach opportunities exist through the media, the internet, museums and space centres, and through the use of hands-on portable exhibits. In education, CubeSats provide a powerful platform at all levels and for the first time satellite technology could be commonplace in the classroom.

<u>Net impact</u>

Benefits to satellite operators

A) The reduced exposure to **TPL in-orbit claims is £94** in present value (based on the reduced liability for costs incurred over and above the £100m insurance cover) ***(5)***

B) The benefits from reduced **insurance are estimated to be £98K** (based on a 49K saving per CubseSat per year in present value) ***(6)***

The increase in total government liabilities

C) The present value increase in **government liability is £132** (based on the expected cost of collision with a satellite of value and expected earnings of 350m and a risk of $3.84*10^{-7}$) ***(5)***

Based on these assumptions the **net impact** of this policy option compared to the status quo is **£98K per CubeSat** over the course of 2 years. This equates to a cost:benefit ratio of over 700.

There are no official estimates of the number of CubeSats that will be launched in future years, let alone how many of those will be UK owned. Clyde Space, a global leader in supplying power systems for CubeSats estimates the growth rate of the market to be in the order of 100%+ but this does not tell us how many of those satellites will be UK owned.

As the number of CubeSats launched increases, costs and benefits will increase in a linear fashion, so that if there were ten in orbit, the net benefits would be around £1m in steady state over the two year lifespan of a CubeSat or £4.7 million in net present value terms over a ten year period.

5) Conclusions and recommendations

The Outer Space Act and its licensing regime for UK space activities need to be updated. During the past 20 years the space industry has changed greatly and the Act has not adapted to these changes. The need to safeguard the Government against third party liabilities needs to be balanced better with the competitiveness of the UK space industry.

We believe that all the above options present a suitable balance between easing the regulatory burden without posing additional undue risks to the Government. Further assurance is provided on the management of risks to the Government by the improvements made to UKSA's pre-licensing technical assessments.

We recommend that policy option 2 is taken forward, with a separate Cubesat proposal at a later date to allow full consideration of the impact.

In response to comments in previous iterations of this impact assessment and from the consultation there are several reasons why the proposal surrounding CubeSats requires further consideration and consequently why they have not been recommended here:

- CubeSats are only one form of nano-satellite that will come to market so it was questioned in the consultation why they should be singled-out in this proposal giving them an unfair advantage.

- Some consultation responses indicated concern over the risks involved in Cubesats which would need to be fully explored by the UKSA before any proposal could be put forward. The fact that Cubesats do not have the capability to propel themselves out of the operational orbital path and so present a hazard to other space vehicles was the driving concern of those consulted.

- The Government does not want to delay capping the unlimited liability to €60 million due to further investigation into CubeSats as for the majority of missions this is likely to benefit UK operators.

- It should be noted that if after a future review additional concessions for CubeSats / nano-satellites were to prove desirable it is unlikely further changes to the Outer Space Act would be required. These could be accommodated within the existing discretionary powers of the Secretary of State.

The table below sets out the monetised costs and benefits of each option individually.

Whilst the analysis above assumed no UK CubeSats were launched the table below includes the calculations from section 5 to enable a complete comparison.

Table 4: Costs and benefits of policy options 2 and 3 and the combined impact

	Costs	**Benefits**	**Net Impact**
Option 2	£1.8m	£13.5m	£11.7m
Option 3 (per CubeSat)	£132	£98K	£98K
Options 2 & 3	£1.8m + £132 per CubeSat	£13.5m + £98K per CubeSat	£11.7m + £98K per CubeSat

<u>One In One Out</u>

This proposal is expected to reduce costs on businesses through reduced expected costs arising from liability for third party claims. This saving is estimated to be equivalent to £1m per annum over the 15 year period (in 2009 prices) this impact assessment considers.

It should be noted that this figure is far lower than the overall benefit to businesses as the majority of benefits arise through the reduction in insurance premiums paid. This proposal will cause a reduction in the cost to satellite operators by removing the indemnity requirement and transferring the extra liability over the insurable €60 to the government. Therefore there are no extra business costs arising from the proposal, as such this proposal is in the scope of OIOO.

<u>Exemption from regulation for micro-businesses and start-ups</u>

Consideration has been given to Micro Business exemption and we have concluded that it should not apply in this case. We believe this measure is out of scope of the moratorium for the following reasons:

- This is a deregulatory measure which will provide savings to industry and should be treated as an 'out' (under one-in, one-out).

- The aim of the Outer Space Act 1986 is to ensure compliance with the UK's obligations under international treaties.

- The licensing regime under the Outer Space Act seeks to ensure that the activity does not pose risks to public health and safety or UK national security. These are areas that should not be compromised by providing exemptions.

Furthermore, this proposal carries no transition costs to businesses - it is purely beneficial to businesses.

<u>Sunset clause</u>

These proposals do not fall in scope of requiring a sunset clause as they do not impose a net burden on businesses.

Alternative to regulation

Changes to regulations are necessary to alter the indemnity requirement as the Outer Space Act is currently legally interpreted as requiring unlimited indemnity. Changes to the insurance requirements, however, do not require a change to regulations as this is a requirement of the licensing regime which the UKSA can change at will.

Specific Impact Tests

Statutory equality duties
After initial screening as to the potential impact of this policy/regulation on race, religion and belief, disability, gender, age, gender reassignment, pregnancy and maternity, and sexual orientation equality, it has been decided that there will not be a major impact upon minority groups in terms of numbers affected or the seriousness of the likely impact, or both.

Competition assessment
The proposals in this impact assessment are not expected to directly or indirectly limit the number or range of suppliers in the industry, limit the ability of suppliers to compete or reduce suppliers' incentives to compete vigorously. As such a detailed competition assessment is not deemed necessary.
The proposals are not intended to impact competition in the domestic market although it is anticipated that their implementation would improve the competitive standing of UK companies in the global context.

Small firms
The proposals are not expected to have a disproportionate negative impact on small firms.

Greenhouse gas assessment
The proposals are not expected to have a significant impact on greenhouse gas emissions.

Wider environmental issues
The proposals are not expected to have a significant impact on the environment.

Health and well-being
The proposals are not expected to have a significant impact on health and well-being

Human rights
We have considered the Human Rights Act and believe that the proposals are compatible with the provisions of that Act.

Justice
The proposals are not expected to have a significant impact on the Justice system.

Rural proofing
The proposals are not expected to have a significant impact on rural communities.

Sustainable development

The proposals are not considered to detract from the principles of sustainable development

Annex 1: Post Implementation Review (PIR) Plan
A PIR should be undertaken, usually three to five years after the implementation of the policy, but exceptionally a long period may be more appropriate**.** If the policy is subject to a sunset clause, the review should be carried out sufficiently early that any renewal or amendment to legislation can be enacted before the expiry date. A PIR should examine the extent to which the implemented regulations have achieved their objectives, assess their costs and benefits and identify whether they are having any unintended consequences. Please set out the PIR plan as detailed below. If there is no plan to do a PIR please provide reasons below.

Basis of the review:
The Government through this impact assessment commits to reviewing this legislation in 5 years time.

Review objective:
The review will seek to establish if the insurance requirement and indemnity limits set are appropriate and whether the CubeSat market has developed how it was anticipated in this impact assessment.

Baseline:
The baseline position is that which is set out in the IA, principally that TPL insurance is set at £100m with unlimited liability falling on private companies.

Success criteria
Increased competitiveness of the UK satellite operating industry in an international context, potentially data on the import and export activity of satellite operators would highlight this result. Other potential metrics include employment and price in the secror. These should all be compared against the expected baseline situation in 2017 had this review not happened.

Monitoring information arrangements:
As more satellites are launched, in particular CubeSats, more reliable data on the number of satellites and incidents leading to TPL claims will be available and will be constantly registered with the UKSA. However, launches will continue to be relatively rare events meaning that assumptions will always have to be made in terms of the limits set.
A number of other metrics could be used to assess the policy:

- Employment levels in the space sector: Standard surveys undertaken by the Office for National Statistics can be used to give an idea what the employment growth in the space sector has been, any cyclical or external factors should be taken into account and wherever possible the direct result of this policy should be estimated.
- Number of firms in the space sector: ONS or business surveys can help assess if there have been a reduction in barriers to entry in the sector due to this review.
- Similar metrics can be used to monitor whether there have been positive or negative effects for employment and revenue in the insurance sector.
- Import/ export data would allow the international competitiveness of satellite operating companies to be monitored.
- More qualititative analysis such as self-response surveys could be disseminated to UK firms that operate satellites; the direct impact of the review can be commented on where quantitative data may be susceptible to other economic forces.
- Data on the price level of satellites would show whether the reduction in regulatory requirements was passed on to consumers in the form of lower prices.

Reasons for not planning a review:
N/A

Annex 2: Risk Analysis for a CubeSat compared with a standard satellite platform

<u>Summary Findings:</u>

- **The direct collision risk in low Earth orbit is reduced by a factor of at least 30 year on year for a CubeSat compared with a standard satellite platform.**

- **Based on the number of resulting fragments from a collision, the indirect collision risk is reduced by a factor of ~10 for the CubeSat compared with the standard platform.**

- **It should be a condition of the licence issuance that cubesats should be injected into orbits which decay naturally within 25 years due to atmospheric drag or have the ability to accelerate this process at higher altitudes (e.g. by the use of inflatable ballutes to increase aerodynamic drag).**

- **Further, CubeSat designers should be encouraged to incorporate appropriate reflectors on the outside of their platforms to enhance their radar cross-section/signatures and therefore their detectability from the ground, in order to minimise the potential collision risk with other operational satellites.**

<u>Analysis:</u>

Probability of Collision

We can assume that the collision probability of satellites within a volume of space is analogous to the kinetic models of a gas where the flux within the volume is given by:

$$F = SV$$

Where *F* is the number of impacts per unit cross-sectional area per unit time, *S* is the spatial density, or the number of objects found within a unit volume, and *V* is the velocity of the objects relative to the detection area.

The average number of collisions, *N*, on an object of collisional cross-sectional area *σ* in a time *t* would then be given by:

$$N = 1 - \exp(-F\sigma t)$$

The collision cross-sectional area between two randomly oriented objects of average radii r_1 and r_2 is given in its simplest form by:

$$\sigma = \pi (r_1 + r_2)^2$$

Secular perturbations to orbits lead to progressive changes in the longitude of node and argument of pericentron of the orbit. The distribution of these parameters for satellites in inclined Earth orbits are nearly random. Under this assumption, spatial density around a central body will not vary with longitude and will only be a function of distance from the body and latitude. The latitude dependence is a function of the inclination of the orbit and the distance dependence is a function of the pericentron and apocentron distances. The relative velocity is a function of pericentron and apocentron distances.

$$N = 1 - \exp\left(-SV\pi(r_1 + r_2)^2 t\right)$$

We can use this expression to determine the relative collision probability with a characteristic space object (representative of the population catalogued by US Space Command) of a CubeSat platform compared to a standard satellite platform in a similar orbit.

The average relative velocity in the low Earth orbit regime (altitude between 150 and 2000 km) is approximately 10 km/s. The average collisional cross-section of a representative satellite with other objects in this orbital regime is ~1.8m^2 .

If the dimensions of a CubeSat are assumed to be 10cm x 10cm x 10cm, then the comparable cross-sectional area for such a body with other objects in the same orbital regime is ~ 0.056 m^2.

The operational lifetime of a CubeSat is of the order of 1-2 years maximum whereas the operational lifetime of a standard satellite in low Earth orbit is of the order of 5 -10 years.

In fact in the expression for N above, if the exponent is orders of magnitude less than 1, simplifies to:

$$N = (SV\sigma t)$$

This shows us that at the same altitude, the relative risk encountered by a CubeSat compared to a standard platform to first order is simply:

$$\frac{N_{cubesat}}{N_{platform}} = \left(\frac{\sigma_{cubesat} L_{cubesat}}{\sigma_{platform} L_{platform}}\right)$$

From above, the σ ratio is 0.056/1.8, and if we assume a 1 year lifetime for a CubeSat and a 5 year lifetime for a representative satellite in this regime, this equates to a factor of ~150 reduction in collision risk in low Earth orbit for a CubeSat compared with a satellite platform that the UK might normally licence (or a factor of ~ 30 year on year).

We can use up to date measurements of spatial density observed by radar systems at different altitudes (attached) following the recent collision of the Iridium 33 and Cosmos 2251 satellites to assess the relative collision risks for the standard satellite and CubeSat platforms considered above.

The spatial densities averaged over orbital inclination are presented in table 1 below.

Spatial Density of tracked objects (objects/km^3)		
Altitude (km)	Year 2004	Year 2010
400	1.0E-09	2.5E-09
500	3.0E-09	5.5E-09
600	6.0E-09	1.35E-08
700	1.0E-08	1.85E-08
800	2.0E-08	2.80E-08

900	1.4E-08	2.75E-08
2010 Density Peaks following Iridium-Cosmos Collision		
780		3.85E-8
850		3.45E-8

Table 1 Spatial density of tracked objects derived from NASA and US Space Command Network

At an altitude of 600 km, this equates to a probability of collision of 7.7E-6 per year for the standard satellite platform, and 2.4E-7 per year for the CubeSat.

Consequences of Collision

We also need to consider the indirect consequences of collision, namely the resulting debris fragment cloud generated and the hazard posed to other satellite platforms. We can derive an empirical expression for the distribution of fragments produced by a catastrophic (hypervelocity impact) collision between two objects in Earth orbit. The number of fragments N_f resulting from the break-up of a satellite of mass M is given by:

$$N_f(>m_f) = 0.8\left(\frac{m_f}{M}\right)^{-0.8}$$

For a CubeSat with a mass of 1kg, and a standard platform with mass of 200kg, the respective fragment distributions are shown in Table 2. If we assume that fragments greater than 10g in mass have the potential to cause catastrophic fragmentation should they collide with another representative object (assume mass = 10kg and therefore N_f >10g = 201 fragments), **then the indirect collision hazard is reduced by a factor of (2208+201)/(32+201) = 10 for the CubeSat compared with the standard platform.**

Number of fragments N_f greater than mass m_f		
m_f	CubeSat (1kg)	Standard Platform (200 kg)
1	201	13929
10	32	2208
100	5	350
1,000	1	55
10,000	0	9
100,000	0	1

Table 2 Number of fragments N_f greater than mass m_f

Other Collision Risk Considerations

Orbital Lifetime

In addition to considering the collision risk during the operational lifetime of a satellite, we are also obliged to consider collision risk during the remaining orbital lifetime, as our obligations under the Outer Space Treaties continue until the object is removed from orbit either naturally (due to the influence of atmospheric drag) or de-orbited using on-board propulsion. Space debris mitigation guidelines endorsed by the United Nations General Assembly in 2007 propose a maximum 25 year orbital lifetime for objects injected into the low Earth orbit “protected region” which extends from 200km to 2000km altitude. The rationale for such action is to limit the recent growth of debris which has resulted in a threefold increase in spatial density in low Earth orbit as shown in Table 1 above. Whereas normal satellite platforms are likely to have propulsive capability and sufficient propellant to perform such manoeuvres at the end of operational life, the size and mass of CubeSats makes this unlikely. Hence **CubeSats should be injected into orbits which decay naturally within 25 years due to atmospheric drag or have the ability to accelerate this process at higher altitudes (e.g. by the use of inflatable ballutes to increase aerodynamic drag) in order to comply with this criterion.**

Trackability

Conjunction analysis (determining the close approach between two objects in orbit) and resulting collision avoidance manoeuvres are now a daily activity for satellite operators. In order to perform such analyses, the orbits of the potential collision partners need to be determined accurately and their trajectories propagated ahead in time to determine possible intersections, and schedule appropriate manoeuvres. As CubeSats are unlikely to have such manoeuvre capability, it is important that they can be tracked in an uncooperative manner (remotely by radar). The dimensions of CubeSats are on the threshold of detectability by such ground-based detectors. Accordingly **CubeSat designers should be encouraged to incorporate appropriate reflectors on the outside of their platforms to enhance their radar cross-section/signatures and therefore their detectability from the ground.**

Prof. R Crowther
STFC/UK Space Agency
25 October 2010

Annex 3: Safety Assessment of Space Activities - UK Outer Space Act Processes

The basis for space flight regulatory environment is derived from Treaties and Principles developed by the United Nations. Since 1961, issues relating to the use of outer space have been dealt with through the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). A Scientific and Technical Subcommittee addresses technical issues associated with the use of space whereas a Legal Subcommittee deals with legal matters. The Executive function of UNCOPUOS is supported by the United Nations Office for Outer Space Affairs (UNOOSA). Four main international treaties have derived from the activities of UNCOPUOS and ratified by the major space-faring nations.

The fundamental and most important treaty to derive from UNCOPUOS is the "Treaty on Principles Governing the activities of States in the Exploration and use of Outer Space, including the Moon and other Celestial Bodies", or as it is more commonly known "the Outer Space Treaty 1967". The OST addresses concepts such as res communis, recognition that space as a global commons, and introduces issues such as international responsibility for national activities in space and associated potential liabilities. These issues are further developed by the subsequent treaties.

The "Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects launched into Outer Space" came into force in 1968 and is more commonly known as the "Rescue Agreement 1968". The Rescue Agreement 1986 is important in establishing "ownership" of space assets and international responsibilities in relation to the activities and property of other state actors. It also establishes the basis of launching authority, an important aspect of space regulation, a role which is further elaborated in the subsequent major outer space treaties.

The third important treaty to derive from UNCOPUOS is the "Convention on international liability for damage caused by space objects" which came into effect on 29 March 1972, and is more commonly known as the "Liability Convention 1972". This states that a launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft flight. In the event of damage being caused elsewhere than on the surface of the earth to a space object of one launching State or to persons or property on board such a space object by a space object of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible.

The last of the major Outer Space Treaties is the Convention on Registration of Objects Launched into Outer Space, which came into effect on 14 January 1975 as is more commonly referred to as the "Registration Convention 1975". The Registration Convention addresses the important issue of notification of activities to third parties, and establishes a key role for the United Nations through its Office for Outer Space Affairs (UNOOSA).

The Registration Convention provides that a launching State should furnish to the United Nations, as soon as practicable, the following information concerning each space object:

- Name of launching State;
- An appropriate designator of the space object or its registration number;
- Date and territory or location of launch;
- Basic orbital parameters, including:
- Nodal period (the time between two successive northbound crossings of the equator - usually in minutes);

- Inclination (inclination of the orbit - polar orbit is 90 degrees and equatorial orbit is 0 degrees);
- Apogee (highest altitude above the Earths surface - in kilometres);
- Perigee; (lowest altitude above the Earths surface - in kilometres);
- General function of the space object.

This information, although useful for identifying the launch of a space object, has limited operation value in determining the position of the space object once initial injection into orbit has been performed.

National Space Legislation

Many countries have reflected their obligations under the Outer Space Treaties through the enactment of national legislation. The Outer Space Act 1986 (OSA) is the legal basis for the regulation of activities in outer space (including the launch and operation of space objects) carried out by persons connected with the United Kingdom. The Act confers licensing and other powers on the Secretary of State acting through the UK Space Agency. The Act ensures compliance with UK obligations under the international conventions covering the use of outer space. Under the legislation of the OSA, the Secretary of State shall not grant a licence unless he is satisfied that the activities authorised by the licence will not jeopardise public health or the safety of persons or property, will be consistent with the international obligations of the United Kingdom, and will not impair the national security of the United Kingdom. Further the Secretary of State requires the licencee to conduct his operations in such a way as to prevent the contamination of outer space or adverse changes in the environment of the Earth, and to avoid interference with activities of others in the peaceful exploration and use of outer space.

The Secretary of State may make regulations prescribing the form and contents of applications for licences and other documents to be filed in connection with applications; regulating the procedure to be followed in connection with application and authorising the rectification of procedural irregularities; prescribing time limits for doing anything required to be done in connection with the application and providing for the extension of any period so prescribed; and requiring the payment to the Secretary of State of such fees as may be prescribed. A licence describes the activities authorised by it and shall be granted for such period, and is granted subject to such conditions, as the Secretary of State thinks fit.

Further a licence may contain conditions which permit inspection by the Secretary of State of the licencee's facilities and inspection and testing by him of the licencee's equipment. It also requires the licencee to provide such information as the Secretary of State thinks fit concerning the nature, conduct, location and results of the licencee's activities.

The OSA provides the necessary regulatory oversight to: consider public health and safety, and the safety of property; to evaluate the environmental impact of proposed activities; to assess the implications for national security and foreign policy interests; and to determine financial responsibilities and international obligations.

There are several key components to the launch licensing process. Pre-application consultation which occurs prior to the formal submittal of a licence application; evaluation, considering through interagency review the information provided by the applicant on the proposed activity; licence issue qualified for the particular activity proposed by the applicant; finally, compliance monitoring, performed after the licence has been issued.

The following is a brief description of the relevant components of the launch licensing process:

> **Socio-political evaluation** aims to determine, at a policy level, whether the proposed mission(s) pose(s) a threat to national security or foreign policy interests, constitutes a hazard to public health and safety or safety of property, or is inconsistent with international obligations. A major element is the interagency review which allows government departments and agencies to examine the proposed mission from their unique perspectives. An interagency review provides relevant government departments and agencies with the opportunity to determine if the mission(s) adversely impact(s) their areas of responsibility or authority. In the policy review, a Licence application is reviewed to determine whether it presents any issues affecting national security, foreign policy interests, or international obligations.

Safety evaluation aims to determine whether an applicant can safely conduct the launch of the proposed launch vehicle(s) and any payload. Because the licencee is responsible for public safety, it is important that the applicant demonstrate an understanding of the hazards involved and discuss how the operations will be performed safely. There are a number of technical analyses, some quantitative and some qualitative, that the applicant must perform in order to demonstrate that their commercial launch operations will pose no unacceptable threat to the public. The quantitative analyses tend to focus on the reliability and functions of critical safety systems, and the hazards associated with the hardware, and the risk those hazards pose to public property and individuals near the launch site and along the flight path, to satellites and other on-orbit spacecraft. The qualitative analyses focus on the organisational attributes of the applicant such as launch safety policies and procedures, communications, qualifications of key individuals, and critical internal and external interfaces.

Compliance monitoring is performed to ensure that a licencee complies with the Act, the regulations, and the terms and conditions set forth in its licence. A launch licencee shall allow access by, and co-operate with, employees or other individuals authorised by the relevant agency to observe any activities of the licencee, or of the licencee's contractors or subcontractors, associated with the conduct of a licenced launch.

Safety/Technical Evaluation

The qualitative and quantitative criteria used for licence evaluation are based on standards and practices employed by a variety of formal bodies. The information considered as part of the licence application process include the information listed below. In applying best practice evaluation criteria to this process, and pursuing a strong compliance monitoring programme (e.g. tracking operational UK satellites to confirm orbit locations), it is possible to understand the nature of potential hazards, apply appropriate risk management methodologies and thereby significantly reduce the likelihood of a catastrophic event occurring.

It is difficult to quantify the direct impact of regulation on the safety performance of a space system, however qualitatively we can see that the comprehensive information required of applicants outlined in Annex A and the detailed assessment of this information as outlined in Annex B can lead in a reduction in the likelihood of an accident, and also mitigate the impact of such an event. Established launch vehicles have a reliability in excess of 0.95, and even if an accident should occur with such vehicles, the remoteness of many launch ranges and appropriate analysis of failure scenarios minimises the potential impact on third parties. In orbit, similarly satellites have a very high reliability linked to mission assurance and operators are increasingly performing conjunction event analysis to avoid possible collisions in orbit. In fact very recent initiatives by US Space Command have seen notification of potential collision events many days in advance to allow operators to take appropriate actions to avoid an accident.

Annex A Generic Information Required for Safety Assessment

General Description of Launch Vehicle:

- Launch range and operator(s).
- Schedule of launch(es).
- Contractors and manufacturers (including integration).
- Flight heritage.
- Proven and projected reliability (including redundancies).
- Test and qualification history
- Performance and operating characteristics.
- Mass & dimensions.
- Description of propulsion system (design, functionality)
- Propellants (mass, hazard classification).
- Flight control system (heritage, operating characteristics)
- Flight safety system (functionality, heritage)
- Payload accommodation (characteristics, environments)

General Description of Vehicle Flight Profile:

- Launch trajectory/azimuth.
- Ground track (IIP), including any overflight of land masses.
- Sequence of major events from liftoff to impact/orbit.
- Nominal impact locations for discarded hardware.
- If orbital, parking, transfer and final orbits.
- Identify any unique aspects of launch.
- Flight termination criteria

General Description of Payload:

- Characteristics of payload(s).
- Mass & dimensions.
- Owner/operator of payload(s).
- Payload function(s).
- Status of licence application (if separate).
- Electromagnetic frequency range.
- Propellant (amount, hazard classification)
- Materials involved in mission(s) that could pose a unique hazard

Safety Organisation:

- Safety characteristics and accreditation of launch range.
- Safety officials terms of reference.
- Range safety procedures.
- Relationship between range's safety organisation and applicant's corporate structure.
- Statement of authority of key positions involved in the launch responsible for critical decisions during countdown.

Applicant's assessment of risks to public from normal and abnormal events for all phases of mission to include:

- Vehicle's ascent to orbit.
- On-orbit risks including collision and risks to operational satellites.
- Reentry risks.
- The assessment is to include for each phase:
- Explanations of hazards or risks.

- Potential failures and their likelihoods.
- Consequence of the above failures.
- Procedures and assumptions used in estimating risks.
- How public will be protected from normal and abnormal conditions.
- Similarities and differences from past vehicles/launches.
- Methods employed to control/manage these risks.

Other Safety Issues:

- Identify party with operational control of each mission phase or element.
- Point or event where applicant's responsibility ends and customer's begins with respect to payload.

Plan for launch readiness reviews addressing:

- Flight safety rules (development, maintenance and compliance monitoring)
- Description of key participants
- Procedures for assessing readiness of range, launch vehicle, payload, flight safety system
- Launch constraints.
- Plan to approve launch checklists to ensure pertinence and consistency.
- Abort procedures.
- Hold procedures.
- Recycle procedures.
- Plan for dress rehearsals including simulations of nominal and off-nominal launch conditions, practice aborts, criteria defining a successful rehearsal
- Pre-launch rest periods for key launch participants and crew readiness evaluation.
- Demonstration of adequacy of launch readiness procedures
- Network provisions for decision-makers direct access to real-time information.
- Requirements for the use of radio/telephone terminology and protocol.
- Network provisions for key participants to monitor intercom.

Accident Plan:

- Identifies reporting criteria and procedures to UK Space Agency
- Describes process
- Investigation boards, committees or officials
- Identifies criteria for preserving data/physical evidence

Pre-Launch:

- Supervision and coordination of hazardous activities.
- Storage and handling of hazardous materials.
- Training and qualification of safety personnel.
- Emergency plans.

Annex B Detailed Analysis of Space System Characteristics

Task Description	Detailed Considerations
Establish details of launch system	What is the system called? Who is responsible for integration of the launch system (primary focus is on the stages and the payload), when are integration functions performed and if relevant where? What are the dimensions of the integrated vehicle (this refers to the total length of the integrated system and the maximum diameter of the vehicle)? How does the system work in general terms, (information relating to the stages should be recorded under the sections specific to the respective stages). Establish a general schematic of the system functionality. What is the main sequence of events from launch to orbital injection in relation to launch vehicle operation (e.g. pitch-over, stage ignition, throttling, and shutdown, separation, jettison)?
Judge quality of data on launch system	Is the information provided by the applicant promotional in nature (e.g. user guide, press release)? Is it supported by independent assessment by FAA or public or restricted domain review? Is the information provided configuration controlled information? How are updates managed?
Check consistency of data on launch system	Does applicant-provided information agree with public/restricted domain independent information? Does applicant provided information agree with FAA review if applicable? Does this information agree with the baseline system description used for the risk assessment?
Consider effectiveness of performance of launch system	What is the performance of the integrated system (i.e. the ability to inject a payload of a particular mass into a specified orbital altitude and inclination)? Where a range of orbits are referred to, all should be recorded, it is important that the capability for the orbit specific to the licence application be established.
Establish conformance of launch system to recognised norms	Are the performance specifications consistent with vehicles of similar design and operation?
Establish details of 1st stage	What is the name of the stage? Which engine is used? Who is the manufacturer/provider of the stage? What is the dry mass (excluding propellants) of the stage? What is the wet mass of the stage (including propellants)? What propellants are used (solid/liquid, fuel and oxidiser)? What are the amounts of the respective propellants used (mass and volume)? What are the hazard classifications of any propellants used? What is the design of the stage (establish schematic showing relative locations of primary components). How does the stage work (e.g. what is the nature of the engine function, what is the form of propellant feed, number of pumps, combustion/thrust chambers, etc). The separation sequence and the means to effect separation and any associated interfaces should be identified.
Judge quality of data on 1st stage	What is the source material provided by the applicant (marketing material, test evaluations?) How current is the information? Has the information been provided by the system prime contractor or stage contractor? Is information within a submission consistent? Is the information consistent with public domain sources? Is the information supported by independent evaluation (e.g. FAA assessment?)
Check consistency of data on1st stage	Where information is available, record the following in order to compare predictions of nominal characteristics with measurements/ telemetry: propellant flow rates (fuel and oxidiser), chamber pressures, propellant pressures, pump pressures and tank pressures, chamber wall temperatures, propellant temperatures and nozzle temperatures,

	sequencing of ignition, and the operation of valves and switches
Consider effectiveness of performance of 1st stage	What is the thrust of the stage at sea level and in a vacuum? Is this consistent with anticipated system performance? Is this possible with engine design and fuel provision?
Establish conformance of 1st stage to recognised norms	Is propellant (fuel and/ or oxidiser) used by other systems? Are there unique hazards with propellants? Does functionality of system differ greatly from other established systems?
Establish details of 2nd stage	What is the name of the stage? Which engine is used? Who is the manufacturer/provider of the stage? What is the dry mass (excluding propellants) of the stage? What is the wet mass of the stage (including propellants)? What propellants are used (solid/liquid, fuel and oxidiser)? What are the amounts of the respective propellants used (mass and volume)? What are the hazard classifications of any propellants used? What is the design of the stage (establish schematic showing relative locations of primary components). How does the stage work (e.g. what is the nature of the engine function, what is the form of propellant feed, number of pumps, combustion/thrust chambers, etc). The separation sequence and the means to effect separation and any associated interfaces should be identified.
Judge quality of data on 2nd stage	What is the source material provided by the applicant (marketing material, test evaluations?) How current is the information? Has the information been provided by the system prime contractor or stage contractor? Is information within a submission consistent? Is the information consistent with public domain sources? Is the information supported by independent evaluation (e.g. FAA assessment?)
Check consistency of data on 2nd stage	Where information is available, record the following in order to compare predictions of nominal characteristics with measurements/ telemetry: propellant flow rates (fuel and oxidiser), chamber pressures, propellant pressures, pump pressures and tank pressures, chamber wall temperatures, propellant temperatures and nozzle temperatures, sequencing of ignition, and the operation of valves and switches
Consider effectiveness of performance of 2nd stage	What is the thrust of the stage at sea level and in a vacuum? Is this consistent with anticipated system performance? Is this possible with engine design and fuel provision?
Establish conformance of 2nd stage to recognised norms	Is propellant (fuel and/ or oxidiser) used by other systems? Are there unique hazards with propellants? Does functionality of system differ greatly from other established systems?
Establish details of 3rd stage	What is the name of the stage? Which engine is used? Who is the manufacturer/provider of the stage? What is the dry mass (excluding propellants) of the stage? What is the wet mass of the stage (including propellants)? What propellants are used (solid/liquid, fuel and oxidiser)? What are the amounts of the respective propellants used (mass and volume)? What are the hazard classifications of any propellants used? What is the design of the stage (establish schematic showing relative locations of primary components). How does the stage work (e.g. what is the nature of the engine function, what is the form of propellant feed, number of pumps, combustion/thrust chambers, etc). The separation sequence and the means to effect separation and any associated interfaces should be identified.
Judge quality of data on 3rd stage	What is the source material provided by the applicant (marketing material, test evaluations?) How current is the information? Has the information been provided by the system prime contractor or stage contractor? Is information within a submission consistent? Is the information consistent with public domain sources? Is the information supported by independent evaluation (e.g. FAA assessment?) Does applicant-provided information agree with public/restricted

	domain independent information? Does this information agree with the baseline system description used for the risk assessment? Does the information agree with the launch system definition?
Check consistency of data on 3rd stage	Where information is available, record the following in order to compare predictions of nominal characteristics with measurements/ telemetry: propellant flow rates (fuel and oxidiser), chamber pressures, propellant pressures, pump pressures and tank pressures, chamber wall temperatures, propellant temperatures and nozzle temperatures, sequencing of ignition, and the operation of valves and switches
Consider effectiveness of performance of 3rd stage	What is the thrust of the stage at sea level and in a vacuum? Is this consistent with anticipated system performance? Is this possible with engine design and fuel provision?
Establish conformance of 3rd stage to recognised norms	Is propellant (fuel and/ or oxidiser) used by other systems? Are there unique hazards with propellants? Does functionality of system differ greatly from other established systems?
Establish details of payload adapter	Who is the manufacturer/provider of the payload adapter? How is the payload separated from the stage (pyrotechnics / springs / bolt cutters / ejected debris captured)? What are the predicted flight environments (static, vibration, acoustic, shock, thermal, electromagnetic radiation)?
Judge quality of data on payload adapter	How are flight environments (static, vibration, acoustic, shock, thermal, electromagnetic radiation) predicted (flight test/ simulator/ combination)? Recognised approach?
Check consistency of data on payload adapter	Comparison of measured flight environments (static, vibration, acoustic, shock, thermal, electromagnetic radiation) with predicted?
Consider effectiveness of performance of payload adapter	Are the environments so extreme so as to have a potential impact on the payload/ flight vehicle integrity? Are the environments consistent with those provided by other vehicles of a similar nature for a comparable payload?
Establish conformance of payload adapter to recognised norms	Are the environments provided by the payload adapter consistent with those for comparable vehicles?
Establish details of payload	What is the wet and dry mass? What are the dimensions of the body and major appendages (stowed and deployed)? What is the primary function of the vehicle, (e.g. mobile/direct broadcast communications, Earth observing radar/optical system, etc)? What is/are the propellant(s) used? What volume and mass of propellant(s) is used? What is the hazard classification of propellant(s)?
Judge quality of data on payload	Is the information provided by the applicant promotional in nature (e.g. user guide, press release)? Is it supported by independent assessment by FAA or public or restricted domain review? Is the information provided configuration controlled information? How are updates managed? What is licensing status of payload [BNSC (OSA), OST/FCC] ?
Check consistency of data on payload	Does applicant-provided information agree with public/restricted domain independent information? Does applicant provided information agree with FAA review if applicable? Does this information agree with the baseline system description used for the risk assessment? If applicable, is information provided by launch licence applicant consistent with information provided by payload applicant?
Consider effectiveness of performance of payload	Does the payload appear to have the capability to perform its intended function? Are comparable systems functioning in orbit?
Establish conformance of payload to recognised norms	Does payload represent any unique safety hazards (i.e.. contaminant of terrestrial and orbital environment, e.g. radioisotopes/ tethers/ fragmentation)? Payload consistent with frequency management issues? Potential for frequency interference?

Establish details of launch range	What is the name of the site/range? Geographic location (longitude/latitude)? Which country? What is the range of times and dates for launch epoch/launch window? Who is responsible for the operation of the range?
Judge quality of data on launch range	Is the information provided by the applicant promotional in nature (e.g. user guide, press release)? Is it supported by independent assessment by FAA or public or restricted domain review? Is the information provided configuration controlled information? How are updates managed?
Check consistency of data on launch range	Does applicant-provided information agree with public/restricted domain independent information? Does applicant provided information agree with FAA review if applicable? Does this information agree with the baseline system description used for the risk assessment?
Consider effectiveness of performance of launch range	Does the launch range provide adequate safety overview? What safety systems are located at range? Are these sufficient? Is range licensed? What is the heritage of the range?
Establish conformance of launch range to recognised norms	How does operation compare with US government ranges? How does operation compare with US commercial ranges? How does operation compare with CSG Kourou?
Establish details of flight profile	What is the direction of launch (azimuth) from the site? Establish altitude-range time profile. What are the state vector and acceleration, pitch, roll, yaw and rates? What are the nominal impact locations for jettisoned objects (e.g. stages/shrouds/ fairing)? What is the unique event sequence for this system and launch range (ignition, staging, jettison, maximum Q, maximum acceleration, throttling, pitch, roll, yaw manoeuvres)? For the instantaneous impact point, what are the permissible limits of excursion? For parking and transfer orbits what are the semi-major axis, eccentricity, inclination, argument of perigee, right ascension of ascending node, epoch at each defined orbit For operational orbits what are semi-major axis, eccentricity, inclination, argument of perigee, right ascension of ascending node, epoch(s)? For disposal orbit what are semi-major axis, eccentricity, inclination, argument of perigee, right ascension of ascending node, epoch Are there any unique aspects of launch and injection such as dog legs, low thrust manoeuvres, reusable/recoverable system elements?
Judge quality of data on flight profile	Is the information provided by the applicant promotional in nature (e.g. user guide, press release)? Is it supported by independent assessment by FAA or public or restricted domain review? Is the information provided configuration controlled information? How are updates managed?
Check consistency of data on flight profile	Does applicant-provided information agree with public/restricted domain independent information? Does applicant provided information agree with FAA review if applicable? Does this information agree with the baseline system description used for the risk assessment?
Consider effectiveness of performance of flight profile	What weather correction contingency has been applied in establishing limits of excursion? Are these consistent with the wind/weather restrictions? What performance tolerance contingency has been applied?
Establish conformance of flight profile to recognised norms	Does the flight profile avoid populated regions where possible? Are significant populations exposed to potential risk?
Establish details of flight safety systems	The purpose of a flight safety system is to destroy, halt, or neutralize the thrust of an errant vehicle before its debris can be dispersed off-range and become capable of causing damage or loss of life. Without a flight termination capability on a launch vehicle, the resulting debris could land on a population centre and/or result in considerable damage. The flight safety system should be able to ensure thrust termination, inhibit ignition, prevent self propulsion, ensure

	dispersion of propellants and prevent detonation of remaining propellants. Is the system operated by radiocommand or is it autonomous? Can the system monitor the launch vehicle performance and determine whether the vehicle is behaving normally, or failing? Can it determine the state vector of the vehicle and predict where the vehicle or pieces of the vehicle will impact in case of failure and if flight termination action is taken? Can it determine if there is a need to delay or abort the launch, or terminate the flight, based on a comparison of predetermined criteria with the current vehicle status? if necessary, can it abort the mission either by commanded vehicle destruct or thrust termination? What has this system be applied to before? What is the record of the system (ie has it been initiated/ has it failed?)
Judge quality of data on flight safety systems	Where is the data derived from? Is it from a manufacturer? Is it independent in nature/source? Is it promotional material? What is the heritage (flight history, with this vehicle) of the flight safety system?
Check consistency of data on flight safety systems	Is the system compatible with the nature of the launch vehicle? Is the reliability/redundancy of the system considered in the risk assessment? Is it consistent?
Consider effectiveness of performance of flight safety systems	Has the flight safety system been used before? On this vehicle? What was the outcome? How does it work? Is this consistent with launch vehicle (i.e. thrust termination for liquid, explosive breakup for solid systems)?
Establish conformance of flight safety systems to recognised norms	What is the reliability of the system? Is it used in other launch vehicles? What was the testing regime that the system underwent? What redundancy is used? What failsafe mechanisms are in place?
Establish details of testing	Requirements for development testing depend upon the maturity of the subsystems and units used, and upon the operational requirements of the specific programme. Development tests should be used to confirm structural and performance margins, manufacturability, testability, maintainability, reliability, life expectancy, and compatibility with system safety. Qualification tests are conducted to demonstrate that the design, manufacturing process, and acceptance programme produce mission items that meet specification requirements. Each flight item which has to be acceptance tested should have undergone a corresponding qualification test. Acceptance tests are conducted to demonstrate the acceptability of a deliverable item. The tests should demonstrate conformance to specification requirements and provide quality-control assurance against workmanship or material deficiencies. Acceptance testing is intended to stress screen items to precipitate incipient failures due to latent defects in parts, materials, and workmanship. The testing should <u>not</u> create conditions that exceed appropriate design safety margins or cause unrealistic modes of failure. In order to establish the level of rigour of a testing campaign for licensing purposes, a full data set for the complete vehicle may not be necessary or practicable. If a subset of these data is considered for this purpose, then it should include key elements such as the flight safety system, which is a fundamental and critical element of the risk management process.
Judge quality of data on testing	**The maximum and minimum expected temperature should have been determined analytically from thermal model predictions using worst-case combinations of equipment operation, internal heating, vehicle orientation, solar radiation, eclipse conditions, ascent heating, descent heating and degradation of thermal surfaces during the service life.** The analytical thermal model should then have been

	validated with results from a vehicle thermal balance test involving operational modes that include the worst case hot and cold conditions. Does documentary evidence exist for specific systems, have specifications for tests been identified? he pressure and leakage test demonstrates the capability of fluid subsystems to meet the specified flow, pressure and leakage requirements. Pressurised vessels should comply with appropriate criteria to ensure rupture or explosion does not occur? What specifications were identified? How were they tested? Are results fully documented? EMC acceptance testing should be conducted on vehicles to check on marginal EMC compliance indicated during vehicle qualification testing and to verify that major changes have not occurred on successive production equipment. The limited tests should include measurements of power bus ripple and peak transients, and monitoring of selected critical circuit parameters. What was the result? What systems were considered?
Check consistency of data on testing	Does the documentation set provide a complete audit trail? Is there consistency between data sets (spectrums, sample sizes, approach, etc?
Consider effectiveness of performance of testing	Qualification and acceptance tests for vibration, acoustic and shock environments are based upon statistically expected spectra levels. The level of the extreme expected environment, that should normally be used for qualification testing, is that not exceeded on at least 99% of flights, estimated with 90% confidence. The level of the maximum expected environment, that should normally be used for acceptance testing, is that not exceeded on at least 95% of flights, estimated with 50% confidence.
Establish conformance of testing recognised norms	What were the environments tested? What were the results? The functional test verifies that the electric and mechanical performance of the vehicle meets the performance requirements of the specifications and detects any anomalous condition. Is there evidence that such a test has been performed? Are there specific records? What was the outcome of the test? How were problems rectified?
Establish details of flight tests	Outline the history of the vehicle and its components (e.g. launcher family, previous applications). Record any changes to flight configuration which may have a potential outcome on launch success/performance. Provide a record of previous flights. Detail launch sites, payloads, trajectories flown, outcome of launch i.e. success/failure, if failure, outcome of accident investigation and modification. Any re-testing performed?
Judge quality of data on flight tests	What is the source of the documentation set? Promotional or otherwise? How much technical detail is provided? Can this be verified? Are there other sources of validation?
Check consistency of data on flight tests	How does this relates to previous submissions (baseline/scenario/mission or otherwise?
Consider effectiveness of performance of flight tests	Have the flight tests addressed all critical elements of system? Are there unique range-vehicle implications?
Establish conformance of flight tests to recognised norms	How does the process relate to ISO/ECSS standards and other applicable practices?
Establish details of reliability determinations	It is important that applicants have identified high failure risk components and can demonstrate exploitation of lessons learned from previous systems. Potential process inadequacies can be addressed by designing in fault tolerance. Is there evidence of this? Simplicity of design can also contribute significantly to higher reliability. In a complementary manner, redundancy has a similar benefit. If the reliability of certain components is too low or the consequences of failure too great, such an approach should

	be used. Identify reliability/redundancy philosophies and ensure that they are put into practice.
Judge quality of data on reliability determinations	What is the proven reliability of the system? Look at past record of derivatives of family of vehicles. What is the reliability predicted by the applicant? Is this acceptable compared with normal launch vehicles?
Check consistency of data on reliability determinations	Are these values consistent with those in past determinations? Are they consistent with public domain considerations? Is the determination qualified by assumptions? If so are these assumptions valid?
Consider effectiveness of performance of reliability determinations	Is this reliability acceptable given the circumstances of launch range and launch vehicle? Is this approach rigorous enough? Does it consider all redundancies and failure paths and propagation mechanisms?
Establish conformance of reliability determinations to recognised norms	If reliability growth assumed, basis of assumptions and methods should be presented. In both cases of predicted and proven reliability, outline the techniques used to arrive at these values, are these recognised techniques? Are they appropriate for this case (e.g. statistically rigorous/appropriate)?
Establish details of pre-launch risk assessments	For each event or chain of events: What are the hazards? Has the applicant considered fire, toxic, impact and explosion hazards? Have comprehensive ground hazard analyses been conducted? Are all potential hazards considered (e.g. propellants, pyrotechnics, etc)? What is the probability of a hazardous event? How has this been estimated? Are vehicle are component states correct (e.g. amount of fuel, location for the stage of the flight, etc)?What assumptions are used? If Monte-Carlo estimation used, how many scenarios? Is this statistically significant? What is/are the confidence limit(s)? Are all relevant areas that could be affected considered? Are potential outcomes consistent with applicable health and safety requirements? Are quantity-distance requirements satisfactory for explosion hazards? The ground safety objectives related to ground activities should be comparable to that accepted for other personnel(e.g. industrial) exposed to hazards during their working day. Have all hazardous components been subjected to a detailed hazard analysis to identify and assess safety rules. For explosions, what scaling laws have been used for blast wave propagation? For fire and toxicity, are standard propagation models used? Are assumptions correct?
Judge quality of data on pre-launch risk assessments	How is the information derived? What sources are used? How much is independently derived? What is the nature of supporting information? Are inputs up to date (e.g. size of launch vehicle, propellant loads, etc)
Check consistency of data on pre-launch risk assessments	Are there independent sources of information? Are local health and safety regulations applicable? Are these consistent with risk assessment determinations?
Consider effectiveness of performance of pre-launch risk assessments	Do casualty expectations and potential property damage exceed limits (consider maximum possible loss v maximum probable loss)
Establish conformance of pre-launch risk assessment to recognised norms	What models are used e.g. blast propagation/ chemical toxicity? Are these standard/recognised models?
Establish details of flight risk assessments	For each event or chain of events: Have all failure modes been considered in a comprehensive manner (e.g. functional failure, fatigue failure, failure of combustion/electrical devices, guidance and control errors? Does nominal operation present a hazard? Is the mass and state of the system and components (e.g. fuel) consistent with the phase of the mission? Are explosion, toxic, fire and impact hazards

	considered? Does the payload represent an additional hazard? What is the estimated casualty expectation? What is the population model used for casualty expectation determination, is it standard? What is the resolution of the population matrix?
Judge quality of data on flight risk assessments	Are estimates for failure mode probabilities based upon knowledge of the vehicle's critical systems and/or objective assessment of their reliability and/or historical data? What are the confidence limits? How is debris lethality considered? Are regions or areas exposed to launch operations or accident hazards identified? If these are subdivided into smaller sections, are critical locations of people or buildings specified for subsequent risk calculations? Does the risk analyses consider the probability of debris/fragments from failed vehicle impacting within hazardous distances of personnel or structures in the region? The probability of an impact, P_i, for a public area requires consideration of all failure chains which could endanger it and always implies an FTS failure given that a critical vehicle failure has also occurred, has this been assumed? How are impact footprints determined?
Check consistency of data on flight risk assessments	Has the FTS and its relationship to risk exposure of the public been considered and addressed in a rigorous manner? Which models have been used for failure analysis (FMECA, FHA, etc)? What state propagation models have been used (physical, chemical, motion, etc)? Are these appropriate/recognised for this application?
Consider effectiveness of performance of flight risk assessments	How rigorous is the evaluation? Does it consider land over-flight? Nominal and non-nominal operation? Are there mitigating circumstances for not considering full FMECA?
Establish conformance of flight risk assessment to recognised norms	What is the casualty expectation? Does it exceed 30×10^{-6} for this launch? Are collective casualty expectations for a launch campaign considered? Is this acceptable?
Establish details of orbital risk assessments	For each event or chain of events: Has the probability of collision with large objects during mission operations been assessed? What is the probability of collision between the launch vehicle and ALL objects injected into orbit, including mission related debris? Does the trajectory of the system intersect with key regions such as the geosynchronous orbit? Has the applicant considered the possibility of explosions? How is this dealt with? Is stored energy depleted at end of life? What is the probability that the system will interact with other objects during launch and acquisition? What periods of encounter are considered? Are the population models representative? If active avoidance practised, what form does this take? What are the uncertainties associated with the estimation? Are there any unfounded assumptions? What are the confidence limits? For the orbital population, are lethality assumptions correct? Does the system have suitable physical protection (if required)? Are payloads and upper stages removed from high value regions of space at end of operational life so that they will not threaten future operations? Is the probability of damage resulting from the collision with smaller debris objects during mission operations limited? Are the number, size and orbital lifetime of debris larger than 1 mm released during normal mission operations is limited in accordance with relevant guidelines?
Judge quality of data on orbital risk assessments	Are the collision probability models appropriate (ie statistical/deterministic)? Are epochs correct? Are traffic assumptions correct? Are the models recognised? Are the models acceptable? Are time scales and resolutions (e.g. altitude/ inclination distributions) appropriate?
Check consistency of data on orbital risk assessments	How does this relate to past evaluations? Are the same (appropriate models used in the correct manner with necessary assumptions)?

Consider effectiveness of performance of orbital risk assessments	Does the system comply with recognised norms for operation, acquisition and disposal?
Establish conformance of orbital risk assessment to recognised norms	How do practices and processes relate to ISO/ECSS standards? Are there relevant ISO, ECSS or UN guidance/practice issues? Is this mission compliant?
Establish details of re-entry risk assessments	Does the applicant plan disposal/de-orbit at end of operational life? If removing payload from high value region, is the proposed disposal strategy acceptable (e.g. orbit lifetime, graveyard altitude)? If re-entry, is it controlled or uncontrolled? If controlled re-entry, what process is employed? Likelihood of success? If uncontrolled, what latitude dispersion? What is lifetime and estimated re-entry epoch? What are the uncertainties? What are the confidence limits? What is the casualty expectation? Is this acceptable compared with recognised standards? Are the number and size of debris fragments surviving re-entry heating and impacting the Earth in populated areas minimised? Which models are used for re-entry dynamics, orbital lifetime prediction and debris dispersions? Are they appropriate?
Judge quality of data on re-entry risk assessments	How is the information and estimates derived? Which models have been used? Does DERA have visibility of these models?
Check consistency of data on re-entry risk assessments	Is the data submission consistent with past submissions? Is the correct orbit for disposal given? Are ballistic terms consistent with the returning vehicle? Are lethality estimates correct?
Consider effectiveness of performance of re-entry risk assessments	Is risk on ground minimised? Is the terminal trajectory minimum risk if controlled re-entry? What is the degree of control/confidence in control?
Establish conformance of re-entry risk assessment to recognised norms	How do practices and processes relate to ISO/ECSS standards?
Establish details of safety organisation	What are the respective functions of the partners/operators? Who is responsible for overall mission performance and success? Who is responsible for safety and environmental considerations and for ensuring the safety and environmental criteria are met? Who controls GO/NO GO decisions? Who ensures that launch criteria are met (range, launcher and payload)? Who has oversight and responsibility for training, rehearsals, and reviews? Who is responsible for anomaly investigation and resolution? What are the respective liabilities of the parties involved in the launch process? What are the overall safety requirements and are they compatible with section? What are the health and safety regulations applicable to the launch range? Who is responsible for ground safety? Who is responsible for the supervision and co-ordination of operators? Who is responsible for review and approval of hazardous operations schedules? Who is responsible for supervision and co-ordination of hazardous activities? Who is responsible for the verification of consistency of emergency plans? Who is responsible for the verification of consistency of training? Who is responsible for definition and provision of general safety training? Who is responsible for safety conflict resolution between operators? Who is responsible for the approval of ground flight safety equipment? Has the applicant identified a qualified safety official who is authorised to examine all aspects of flight safety operations? Who will monitor independently personnel compliance with safety polices and procedures? Who shall ensure that all of the safety official's concerns are addressed prior to launch? Who is responsible for the development and maintenance of flight safety rules? Who is responsible for the allocation of flight safety responsibilities and requirements? Who is responsible for the definition and implementation of

	flight safety arrangements? Who is responsible for the identification and assessment of flight safety risks? Who is responsible for the management of residual flight safety risks? Who is responsible for the verification of operator compliance with flight safety rules? Who is responsible for the approval of on-board flight safety equipment? Is the Flight Safety Officer operationally independent of all the space vehicle operators? Is this confirmed by the flight safety rules? Does the flight safety officer have the authority to interrupt the flight of a launch vehicle during the launch phase?
Judge quality of data on safety organisation	The launch site management staff should organise practical safety training suited to safety risks present on the launch site and formalised by the award of a safety qualification certificate or equivalent. This training should be adapted to the changes of hazardous situations and to the occurrence of new safety risks. The content and method of this training should be periodically reviewed and updated. Training of personnel will involve general safety training, specific safety training by launch range, and particular safety training by speciality. The safety rules of an operator should provide detailed objectives of these training levels. The contents of each level should be verified by the ground safety officer. The safety qualification certification awarded by an employer to personnel who have completed a safety training course should specify the level and the limits of its validity. Do personnel have safety education, training, or experience (such as a degree in safety engineering, industrial hygiene, etc.) that is appropriate for their job responsibilities (system safety, flight safety, ground safety, occupational safety and health, etc.)? Have/do personnel receive(d) a specific training for the launch safety risks, responsibilities, facilities, organisation, rules, procedures, etc.? Are the detailed contents of this specific training, depending on the responsibilities to be assumed, specified in detail in each operator safety rules? Does safety training include a description of normal and abnormal operating modes of hazardous items, characteristics of these items, associated safety risks, prevention measures, protection measures, safety implementation circuits, intervention devices and means etc.? Does the training of safety professionals include active participation in simulation sessions of the normal and abnormal operating modes of hazardous items and in exercises for hazardous situations related to catastrophic or critical hazards? Does general safety training allow personnel to know the general hazards and safety risks that exist on the launch site, the preventive measures to be taken, the individual protection measures at disposal, and the notification procedures when an unsafe situation is observed? Does specific safety training by range instruct personnel in the inherent hazardous operations on that range, the associated prevention and protection measures, the emergency plans, and the corresponding rescue means? Is this provided by the range operator? Is specific safety training dedicated to each professional discipline implemented during hazardous operations on a launch site? Is safety training by speciality training specialists in hazardous items necessary for these hazardous operations, in the normal and abnormal operating conditions? When carrying out a hazardous operation on the launch range, what safety accreditation is required? Does this include a health certificate if one is required by the national regulations ? Does this include a certificate of technical competence issued by the employer? Does this require safety certification for the level required by the position? Are only those workers whose safety accreditation is valid authorised to participate in

	a hazardous operation?
Check consistency of data on safety organisation	Are you able to compare documents from different sources relating to same topic? Can you identify clear hierarchies of responsibility and authority? Are they consistent?
Consider effectiveness of performance of safety organisation	Is the safety organisation able to guarantee that all safety issues are identified, assessed and addressed in an adequate manner?
Establish conformance of safety organisation to recognised norms	How do practices and processes relate to ISO/ECSS standards?
Establish details of safety rules	A licence applicant should be able to demonstrate that ground hazard analyses have been performed, and that all hazardous ground operations have been identified. Such analyses should consider the probability of an event occurring and the areas that could be affected. The roles and responsibilities of those involved in assessing, approving, performing, and monitoring hazardous activities should also be defined. In order to achieve safe operations, any hazardous activity and operation performed on or from a launch site and governed by the ground or flight safety rules shall be preceded by the preparation of formalised written procedures. Do such procedures exist? Do they identify the nature of hazardous operations, the environmental conditions, the potential safety risks, hazardous situations, their possible changes, the emergency plans, the necessary safety measures? Are procedures required to have safety warnings in plain language clearly marked in the body of the procedure, at the appropriate step? Are procedures dealing with hazardous operations approved by the concerned safety organisation? Are there constraints to ensure that no change which modifies a risk or adds a hazard can be made without a new approval by the same safety organisation? How are hazardous operations which must be carried out even though they have not been identified during the hazard analysis dealt with? Is its procedure drafted by the affected operator and submitted to the concerned safety organisation for approval before the operation is started? Are all procedures dealing with hazardous operations subjected to an operating hazard analysis before they are approved?
Judge quality of data on safety rules	How is configuration control dealt with? How are updates communicated?
Check consistency of data on safety rules	Do safety rules exist in different forms? If so are they consistent? Are there conflicts at local, national and international levels?
Consider effectiveness of performance of safety rules	Do the safety rules consider all relevant issues? Do they ensure that hazardous conditions/states are avoided/minimised?
Establish conformance of safety rule to recognised norms	How do practices and processes relate to ISO/ECSS standards?
Establish details of safety processes	Does an overall system safety plan exist? Does it define management and operational controls? Does it address system safety engineering? Are safety criteria and requirements established? Are safety audits conducted? If so, outcomes? Has the applicant submitted a communication plan providing launch personnel communications procedures during countdown and flight?
Judge quality of data on safety processes	Are go/no go criteria examined? Are telemetry and communications systems verified? How? Is launch abort practised? Is launch delay practised? Are emergency/contingency responses practised? Outcome(s)?
Check consistency of data on safety processes	Are the safety processes representative of the safety organisation? Are the safety processes appropriate (e.g. rigorous enough)?

Consider effectiveness of performance of safety processes	Does the plan ensure effective issuance and communication of safety-critical information during countdown including hold/resume, go/no go, and abort commands, and describe authority of personnel to issue these commands? Accident Response Plan? Accident Investigation Plan? Who is responsible for respective investigations? Is a board established? If so, Board TORs? Dress rehearsals: Nominal Conditions, Non-Nominal Conditions, Crew Readiness Evaluation, Procedures, Results, Rehearsal Success Criteria? Is countdown procedure practised?
Establish conformance of safety processes to recognised norms	How do practices and processes relate to ISO/ECSS standards?
Establish details of external co-ordination	Who is responsible for air authority (FAA, CAA) co-ordination at international, national and local level? Who is contacted? Where are they located? What information is given? What information is requested? When is this conducted? Why is this conducted? Who is responsible for space authority co-ordination at international, national and local level? Who is contacted? Where are they located? What information is given? What information is requested? When is this conducted? Why is this conducted?
Judge quality of data on external co-ordination	Are contacts current? Are the contacts appropriate? Is adequate information provided? Is information provided in time? Is a review conducted after launch?
Check consistency of data on external co-ordination	Is COLA conducted? Who is responsible? Is COMBO conducted during launch process? Are orbital slots and frequencies authorised? Who is responsible for marine authority co-ordination at international, national and local level? Who is contacted? Where are they located? What information is given? What information is requested? When is this conducted? Why is this conducted?
Consider effectiveness of performance of external co-ordination	Does the external co-ordination address all potential external impacts and environments (e.g. marine, land, air, space)? Does it ensure compliance?
Establish conformance of external co-ordination to recognised norms	How do practices and processes relate to ISO/ECSS standards?
Establish details of launch operation procedures	Pre-launch validation testing is conducted with the objective of demonstrating launch system and on-orbit system readiness and is normally divided into two phases. During the first phase, the test series establishes the vehicle baseline data in the pre-shipment acceptance tests. All factory test acceptance data should have accompanied delivered flight hardware. Is this the case? When launch vehicle and payload(s) are delivered to the launch range, are tests conducted as required to assure vehicle readiness for integration with the other vehicles? These tests should also verify that no changes have occurred in vehicle parameters as a result of handling and transportation to the launch range. The launch vehicle upper stages and/or payload may each be delivered as a complete vehicle or they may be delivered as separate stages and assembled at the launch range. The pre-launch validation tests are unique for each programme in the extent of the operations necessary to ensure that all interfaces are properly tested. For programmes that ship a complete vehicle to the launch range, do these tests primarily confirm vehicle performance, check for transportation damage, and demonstrate interface compatibility? During the second phase, initial operational tests and evaluations are conducted following the integrated system tests to demonstrate successful integration of the vehicles with the launch facility, and that compatibility exists between the vehicle hardware, ground equipment, computer software, and within the entire launch and on-orbit system. These tests

	should ensure compatibility with scheduled range operations including range instrumentation. Is this the case? Do the pre-launch validation tests exercise and demonstrate satisfactory operation of each of the vehicles through each of their mission phases to the maximum extent practicable? Are test data should be compared to corresponding data obtained in factory tests to identify trends in performance parameters? Does each test procedure used include test limits and success criteria? How is launch range readiness established? What security and surveillance measures are employed? How is launch vehicle readiness established? How is the flight safety system readiness established?
Judge quality of data on launch operation procedures	To the greatest extent practicable, the initial operational tests and evaluations should exercise all vehicles and subsystems through every operational mode in order to ensure that all mission requirements are satisfied. These tests should be conducted in an operational environment, with the equipment in its operational configuration, by operating personnel, in order to test the effectiveness and suitability of the hardware and software. Is this conducted?
Check consistency of data on launch operation procedures	Are launch operation procedures consistent with safety organisation, authorities and responsibilities? Are all hazards that were identified addressed accordingly?
Consider effectiveness of performance of launch operation procedures	Are communication networks assigned so that personnel have direct access to real-time safety-critical information? Do safety personnel monitor common intercom channels during countdown and flight? Have protocols been established for employing clearly defined communications terminology? For audio networks supporting launches, do they take the form of commercial services, intercom network communications, and/or dedicated point to point system? If several languages are used, which is the primary one? In the case of dual language, is direct translation provided? Are communications recorded to support anomaly investigation?
Establish conformance of launch operation procedures to recognised norms	How do practices and processes relate to ISO/ECSS standards?